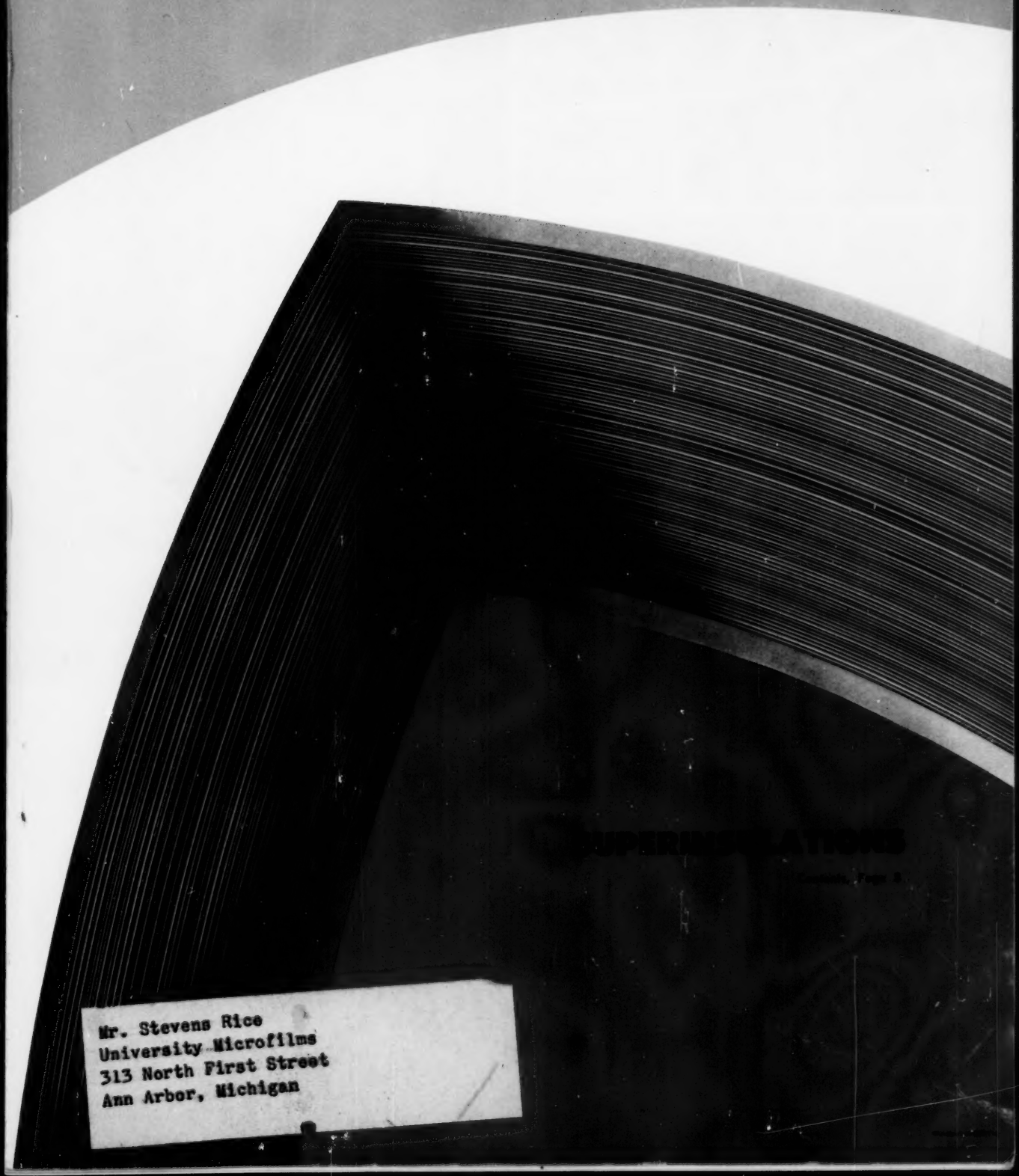
MARCH 2, 1961

MACHINE DESIGN

A PENTON PUBLICATION — BIWEEKLY



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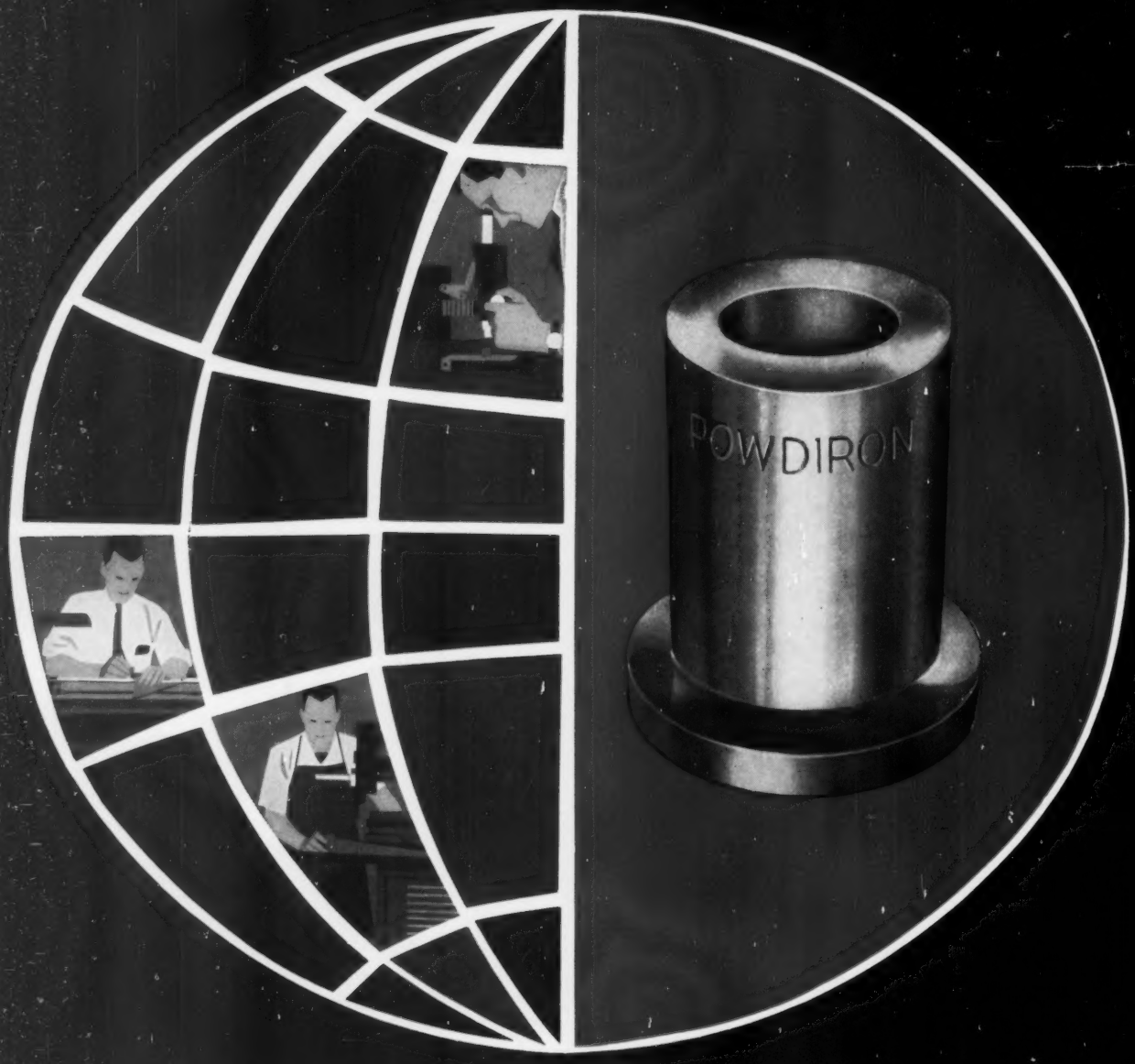

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From Bound Brook's newly-formed association with the world-wide organization of Birfield Limited, comes the new Ferrocite process—making possible economies of operation never before available in self-lubricated iron bearings of Bound Brook quality. The high standards of Powdiron® quality have been retained, but the resultant economies make Bound Brook your best buy in iron bearings. The next time your specs call for self-lubricated iron bearings, it will pay you to call Bound Brook.

BOUND BROOK BEARING
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A BIRFIELD COMPANY

Pioneer in Powder Metallurgy Bearings and Parts • Plants at Bound Brook, N.J. and Sturgis, Mich.

Circle 401 on Page 19

THANK YOU . . .
for your enthusiastic response to this announcement. Because it has been viewed as an important advance in valve development, we reprint this news for those who missed its first appearance.

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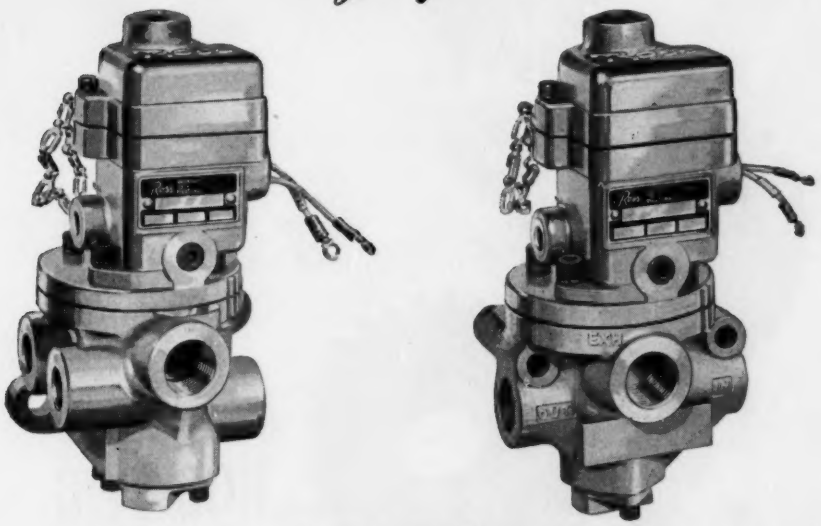
Proudly presents



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A complete new series of inline valves, sizes one-quarter inch through one and one-half inch, straightway, 3-way and 4-way. These valves, size for size, will operate faster, longer, and provide greater capacity than any other valves we have been able to find.

When the price, quality and performance and Ross reputation are taken together in evaluating this series, it represents probably the best valve value available today. Before you specify any valve after today, you owe it to yourself to look into the "Headline" series. Write for full information.

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HOB TWO FOR THE PRICE OF ONE

By switching to a lead-treated steel, Thor Power Tool Company cut the cost of these idler gears in half. Aristoloy 4620 (leaded*) provided high strength with excellent wear and shock resistance qualities. On gear cutting operations, machinability jumped from 35% to 66% (of B 1112). And there was a marked improvement in surface finish.

If you would like to know more about the production economies of lead-treated steels possible on hobbing, broaching, milling, and particularly automatic machining operations, write today for LEADED STEELS CATALOG. Or call your nearest Copperweld representative.

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ARISTOLOY STEELS

DIVISION OF
COPPERWELD STEEL COMPANY

ARISTOLOY STEEL DIVISION 4017 Mahoning Ave., Warren, Ohio • EXPORT: Copperweld Steel International Co., 225 Broadway, New York 7, N. Y.

Front Cover: The sandwich-type insulation of the double-wall vessel shown in artist George Farnsworth's cover design keeps liquid hydrogen in cold storage for long periods of time. For design and application details of such superinsulations for use in cryogenic service, see Randall F. Barron's article on Page 116.

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THE PROFESSIONAL JOURNAL FOR ENGINEERS & DESIGNERS

MACHINE DESIGN

March 2, 1961
Volume 33 — No. 5

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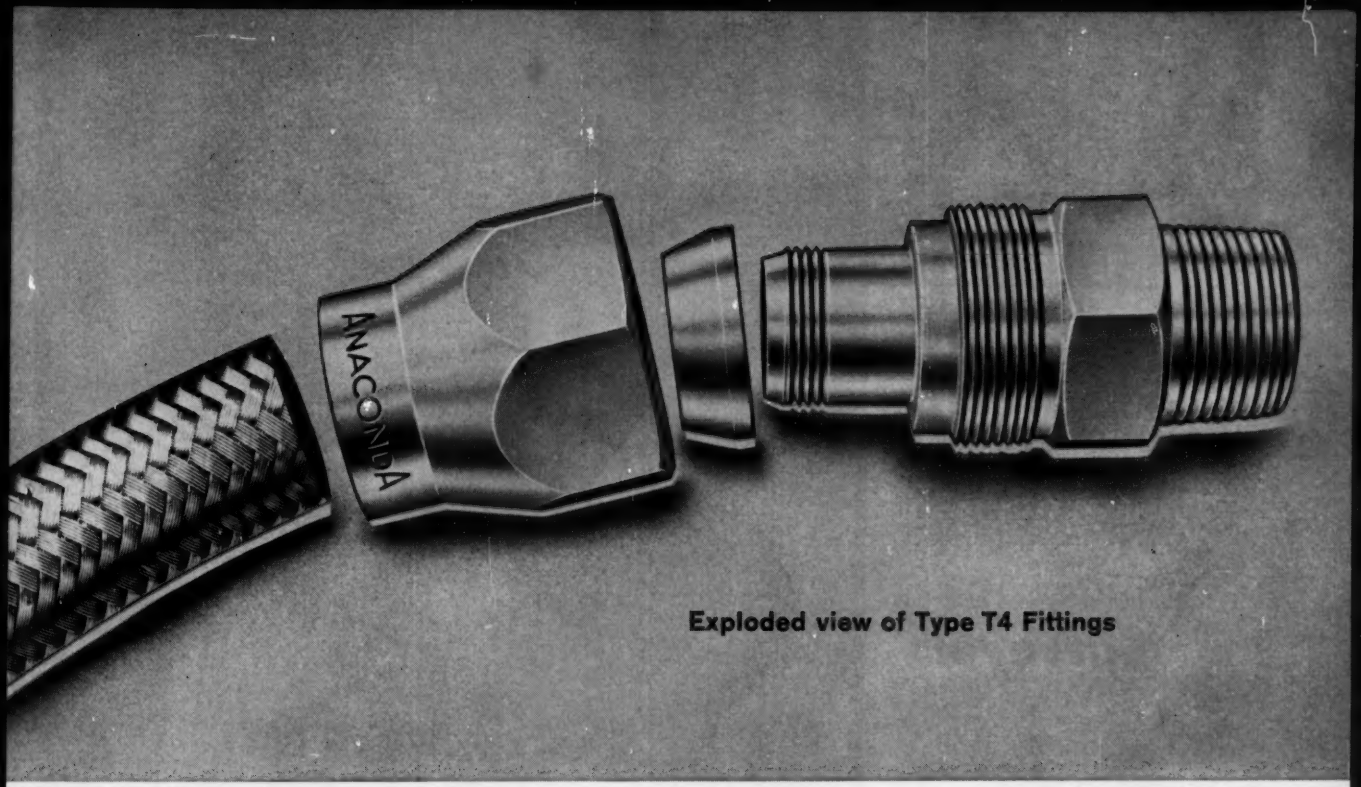


Exploded view of Type T4 Fittings

Tailor-made Assemblies—

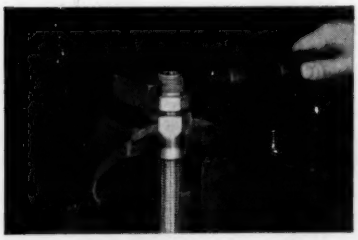
NEW ANACONDA TYPE T4 HOSE OF TEFLON* WITH REUSABLE FITTINGS

Now you can get stainless steel wire-braided hose assemblies of Teflon from your local Anaconda distributor. He can make them up to your exact needs in a matter of minutes, using simple hand tools. It's fast and easy.

Type T4 Hose takes the roughest service. The flexible core is tough virgin Teflon. It's reinforced with stainless steel wire braid for added strength. Reusable fittings for Anaconda Type T4 Hose are designed to withstand high working pressures and temperatures.

Where you can use Anaconda Type T4 Hose. Use it for general industrial uses to handle hydraulic and corrosive fluids, hot tar, steam, air, fuel, food, lubricants and gas—within a temperature range of –65° F through 450° F.

Anaconda Type T4 Hose is available in ⅛-inch through 1¼-inch actual inside diameters. Standard fittings for Type T4 Hose are available in cadmium-plated brass, N. P. T. males. To find out more about how this new assembly can help simplify your maintenance work, fill out the coupon and mail it today. 60126L



It's easy to attach, detach, and reuse Type T4 Fittings. All you need is a vise and a wrench.

*Dupont Trademark

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METAL HOSE

Circle 406 on Page 19

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P. O. Box 791, Waterbury 20, Conn.

Please send me more details about New Anaconda Type T4 Hose and Type T4 Fittings.

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DESIGN ENGINEERING NEWS

Surveyor:

NASA's Soft-Landing Probe Is Designed To Make A Lunar Soil Analysis

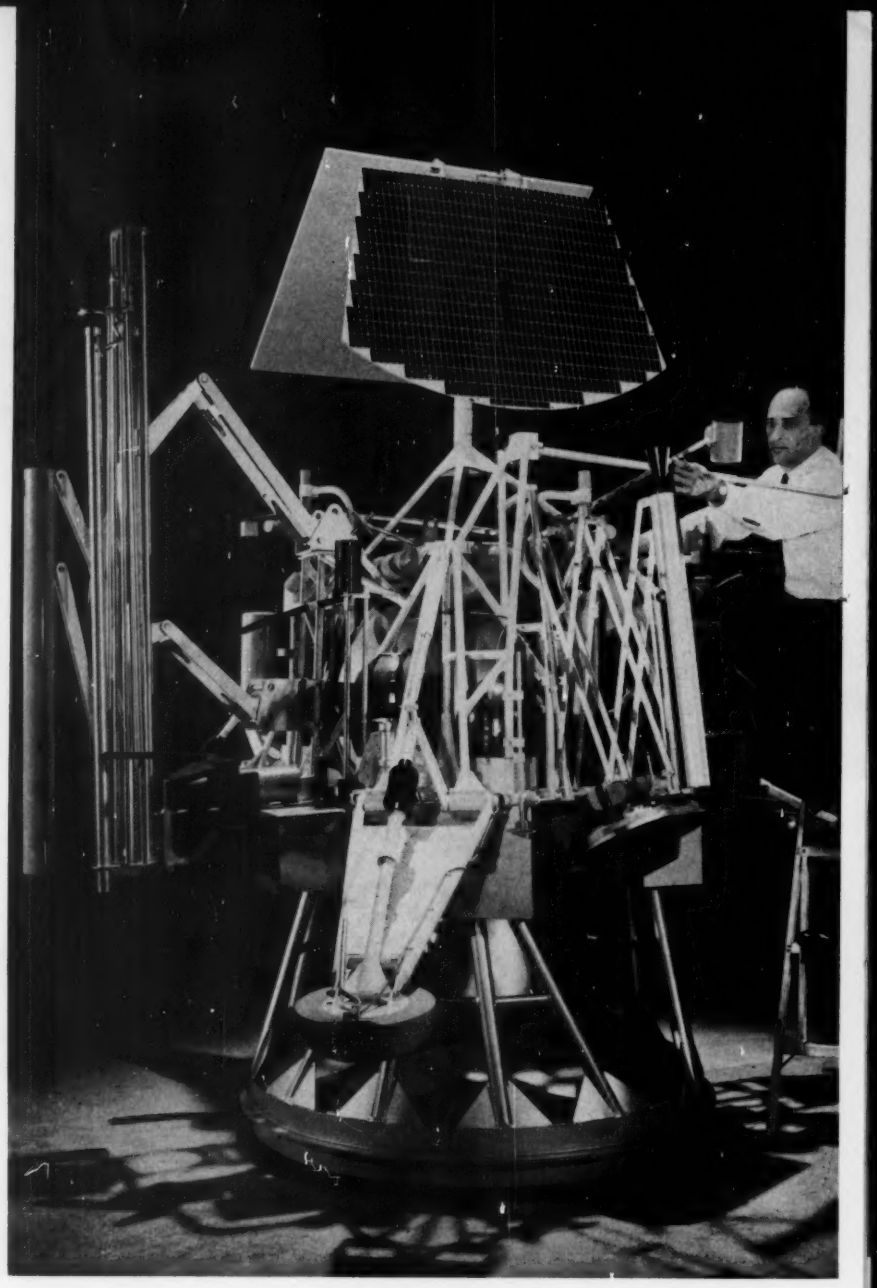
SOMETIME in 1963, U. S. scientists will make an imposing addition to the lunar landscape. The first of a scheduled seven Surveyor vehicles will blast off for a soft landing on the moon carrying the most complex payload ever hurled into space.

Full-scale mockup of the Surveyor vehicle, unveiled by prime contractor Hughes Aircraft Corp., reveals a sparse tubular framework festooned like a Christmas tree with instrumentation. Standing on three high-flotation feet, the structure is 11 ft tall.

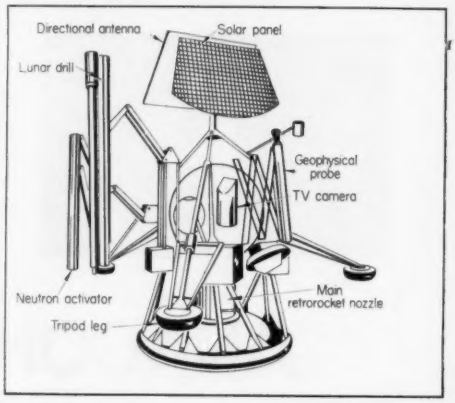
The vehicle will weigh approximately 2500 lb when ejected into its lunar trajectory by an Atlas-Centaur booster. When it lands on the moon at 5 to 10 mph, after its 8000-lb-thrust retrorocket has been fired, it will weigh 750 lb. Communications equipment, structural components, and temperature-control equipment will account for 500 lb of this weight. The remaining 250 lb will consist of sophisticated instruments.

Everything Surveyor sees and feels will be relayed back to radio receivers and television screens on earth. Four TV cameras will scan the horizon; a sensitive seismometer will record moon quakes and meteoritic impacts; other instruments will record gravity and determine whether or not the moon has a magnetic field. As a final accomplishment, Surveyor will perform a lunar soil analysis. A drill, mounted on a pantagraph structure, will unfold after the vehicle lands and bore into the surface for a distance of 18 to 60 in. A second pantagraph structure, mounted on the drill frame, will carry a neutron activator to make the soil radioactive for testing.

Hughes scientists have largely dismissed the danger of Surveyor being swallowed in the predicted layer of porous lunar dust. Laboratory tests conducted on earth indicate that dust tends to pack down tightly in a vacuum.



Surveyor's weight drops to 125 lb in moon's slight gravitational field. Drill is thus designed to operate lightly to avoid tipping the vehicle.



...Fluid Power news

OILGEAR 40 Years of Fluid Power

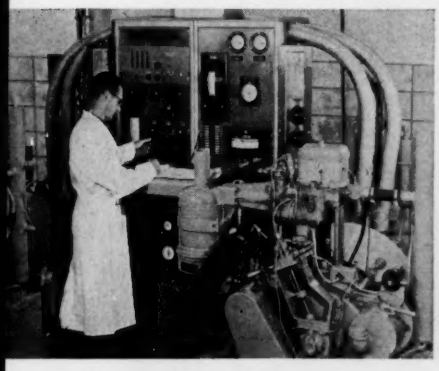
Report No. 12,400 From Oilgear *Application-Engineering* Files

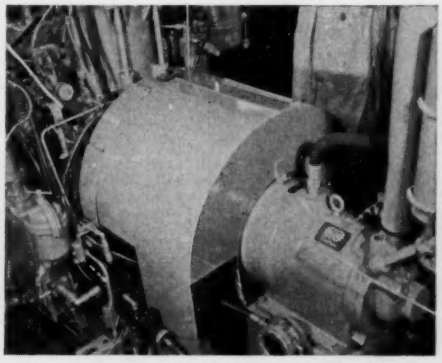
HOW OILGEAR-ESSO RESEARCH TEAMWORK SOLVED NEED FOR MORE COMPACT, LOWER COST, RELIABLE, HIGHLY ACCURATE, DYNAMOMETER AND STARTER SYSTEMS

USER: *Esso Research and Engineering Corp., Linden, New Jersey*

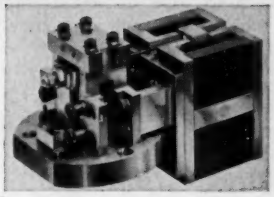
PROBLEM: New Equipment to conduct the exhaustive, standardized performance tests on all new fuels and lubricants, as required by the oil companies and engine manufacturers — to guarantee top-quality petroleum products for optimum consumer engine performance. These extended tests — carefully recorded and regulated from operating control centers — are performed with *standard test* engines coupled to load-absorbing dynamometers. Cradled, expensive electrical load absorbers were previously used to provide test engine control.

ESSO RESEARCH REQUIREMENTS FOR A NEW DYNAMOMETER SYSTEM WERE: 1. Sharply reduce installed cost and valuable test floor space. 2. Insure absolutely reliable, precise, loading and speed control over continuous periods up to 1,000 hours per test. 3. Simplify test engine starting methods — normally 50-hp motors are used to overcome high starting torques, due to heavy flywheels and high internal friction. 4. Long life, maximum trouble-, and maintenance-free durability.

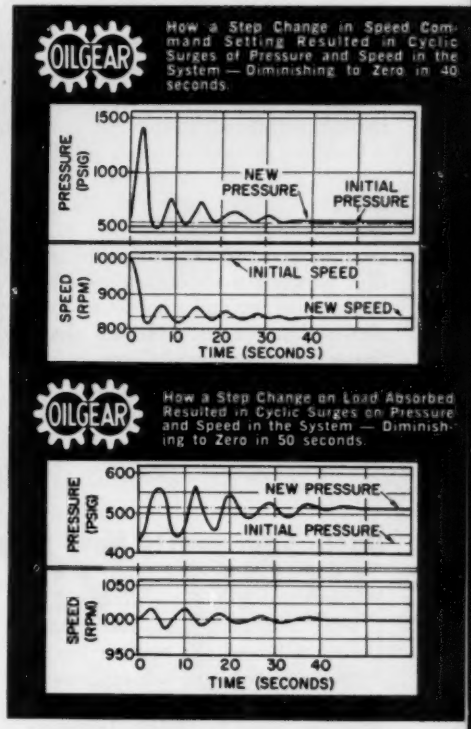




LEFT: One of the **Oilgear-Esso Research** centralized control centers for complete recording, regulation, control, and operation of two test engines, and the Oilgear servo-valve-controlled Dynamometer and Starters connected to them. **RIGHT:** Rear view of 5¾" bore by 8" stroke, Standard Single Cylinder Test Engine with Oilgear servo-valve-controlled Dynamometer/Starter. This efficient, compact, Oilgear pump/motor unit is shaft-coupled to the test engine . . . cranks the engine for starting — then absorbs all power produced during testing. Other system equipment — Oilgear servo-valve "Power Paks" that regulate the loads imposed on the test engines and Oilgear remote, air-controlled Type "DA" Variable Displacement Pump used for starting the test engines — are mounted on the floor above to free valuable test floor area for additional testing units.



SERVOCONTROL* — Single-Stage, Four-Way Servo Valve without enclosure . . . exclusive "Swing-Plate" design . . . only one moving part . . . no metal-to-metal contact . . . as used with this installation.
*A Division of The Oilgear Company



SOLUTION: A completely new servo-valve-controlled *Dynamometer and Starting System* was *Application-Engineered* by Oilgear's Servocontrol Division. In addition to meeting all engine control and starting requirements, these new systems were installed *at 50% of the cost of comparable "universal" electric dynamometer systems.* Addition of two more test units to this system will result in a saving of 65% for the four-ganged arrangement. The unusual, centralized starting system has adequate capacity to start a large number of test engines — one at a time — and maintain the required supercharge on the dynamometer pump/motors during test-loading. Oilgear loading Pump/Motors permit more compact installations than equivalent capacity alternate systems. Simple safety interlocks protect the equipment, and guarantee positive, correct operating sequence of all starting and loading test procedures.

ESSO RESEARCH REPORTS — *"Other than installed cost and space saving, the prime requirement of this dynamometer was to maintain a constant speed for variations in temperature, engine torque, etc. This system maintains an accuracy of 1 rpm at an engine speed of 1000 rpm — or a speed accuracy of 0.1%.*

Information contained in this Fluid Power News Report is condensed from a paper entitled, "Electro-Hydraulic Dynamometer and Starter for Laboratory Test Engine" — by J. W. Broome, Chief Engineer, Servocontrol Division of The Oilgear Company, and R. L. Van Voorhies, Senior Engineer, Mechanical Division, Esso Research and Engineering Company . . . presented at the NCIH — Chicago, Illinois. OILGEAR — SERVOCONTROL are trademarks of The Oilgear Company.

By sizing the hydraulic equipment to torque and speed required, these same fundamental components can be applied to other dynamometer applications . . . and for controlling other variables. OILGEAR-SERVOCONTROL can supply *everything* a carefully engineered system requires . . . reduce delays, costly machine downtime due to malfunctioning, and actually save you money on engineering, components wiring, piping, installation and testing costs — PLUS the assurance that only a "single-source, single-responsibility" can give.

For practical, lowest-cost-per-year solutions to YOUR rotary or linear drive and control problems, call the factory-trained Oilgear Application-Engineer in your vicinity. Or write, stating your specific requirements, directly to . . .

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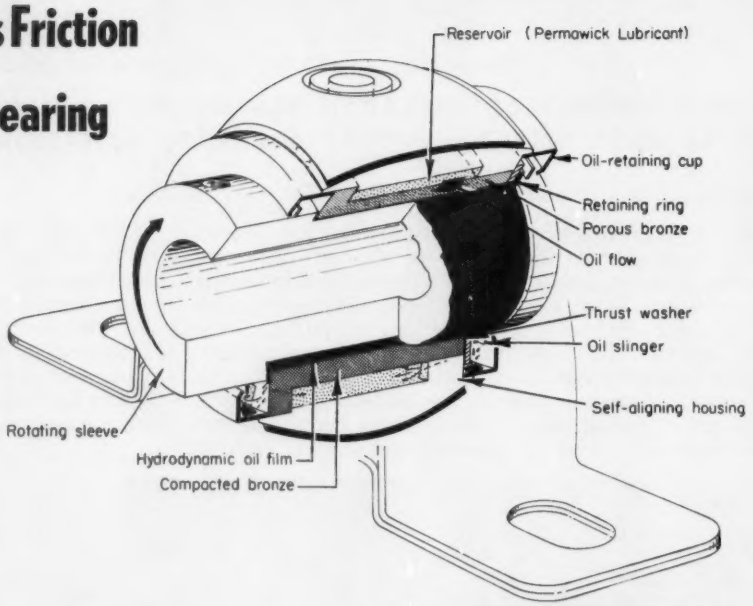
Phone: Mitchell 5-6715 . . . Direct Distance Dialing Code — 414

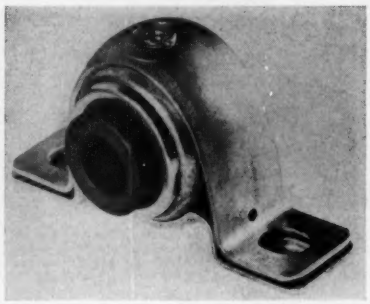
Please direct inquiries to advertiser, mentioning MACHINE DESIGN

Hydrodynamic Film Cuts Friction In Sintered-Bushing Bearing

DETROIT—How to sustain a low-friction hydrodynamic film within a sintered bearing has been a knotty problem for bearing specialists. One promising solution—worked out by Congress Drives Div., Tann Corp.—takes advantage of the tendency of sintered bronze to cold flow and compact under load. Applied to a bearing, the "run-in" operation produces an oil-impervious surface on the section of the bushing under the load. The rest of the sintered bushing remains porous, permitting establishment of a hydrodynamic oil film.

Congress is incorporating its discovery in a new pillow-block bearing line. Lubricated by a lifetime recirculatory oiling system, the bearing generates a hydrodynamic film between a stationary sintered-bronze bushing and a hardened-steel sleeve that rotates with the shaft. Since metal-to-metal contact is eliminated, friction, heat, noise, and vibration are unusually low, says the developer.





Designed to handle loads in the 50-psi range (speeds to 1750 rpm or higher), this pillow-block bearing is said to be the first to take advantage of the low-friction potentials of hydrodynamic-film lubrication. Self-aligning, it incorporates integral inner and outer races (bearing surfaces), allowing operation with unground shafting. Oil slingers and end caps collect oil as it leaves the bearing area, return it to the reservoir.

Uncle Sam Drafts New Inventions-Wanted List

WASHINGTON, D. C.—According to a new "shopping" list, the Armed Forces still need 123 new devices or improvements in present equipment. In an updated edition of *Inventions Wanted*, the National Inventors Council sends an S O S to civilian inventors, requesting that they apply their ingenuity to such items as:

A computer memory device with 0.01 microsecond access time, ten million bit capacity, and a volume of less than 1 cu ft

An automatic mechanism to transfer oral or handwritten information into digital information signals

An electrical generator providing both ac and dc power from shafts turning at 50,000 to 100,000 rpm

A low-energy switching device capable of at least 100 reliable operations

A compact movie camera with a minimum frame rate of 100,000 frames per second and an exposure time of a microsecond or less

A lightweight mechanical arm for remote handling of sensitive pyrotechnic compositions

A converter of heat to electricity with an output exceeding 5000 whr per pound of weight

A new sound—completely distinctive from present sirens, horns, whistles, bells, buzzers, engines, or explosions

Small arms that are virtually noiseless, smokeless, and flashless

A servo-assisted power suit for the individual soldier to increase his strength, endurance, mobility, and resistance to combat environments

A less accurate gyroscope that is also more reliable, cheaper, and lighter weight than present ones, for use in short-range missiles

A power source that utilizes energy from thermal and electrostatic fields which develop around a missile in flight

A method of driving stakes 12 in. into frozen ground

An inventor who can offer a solution to any of these problems, or who has other ideas that would interest the Dept. of Defense, should send details to the National Inventors Council, Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. Copies of *Inventions Wanted* are also available, free, from NIC.

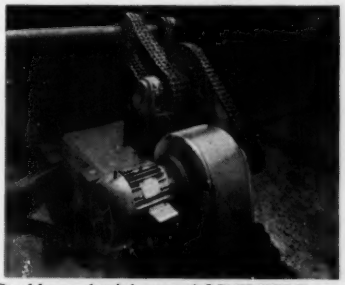
Another of the
invisible extras that
insure the precision performance
of LINK-BELT roller chain

Optical comparator inspection guarantees

precision of every part

Precision is *rigidly practiced* in every step of Link-Belt's roller chain production. The optical comparator is an example of the specialized equipment used to assure precise manufacturing control of chain parts and tools. It is capable of magnification up to 100 times.

Continuous inspection is just one of the *invisible extras* that contribute to the greater strength and endurance of Link-Belt roller chain. Others include precise heat-treat control, prestressing, pitch-hole preparation, shot-peening and burnishing of rollers.



Double- and triple-strand LINK-BELT steel roller chains easily handle the heavy loads encountered by this storage table drive.

These features—plus painstaking precision in every step of manufacture—assure you of chain that can easily cope with today's heavy loads and high drive speeds.

For engineering assistance in applying industry's preferred roller chain, contact your nearest Link-Belt office. See CHAINS in the yellow pages of your phone directory.

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LINK-BELT

ROLLER CHAINS AND SPROCKETS

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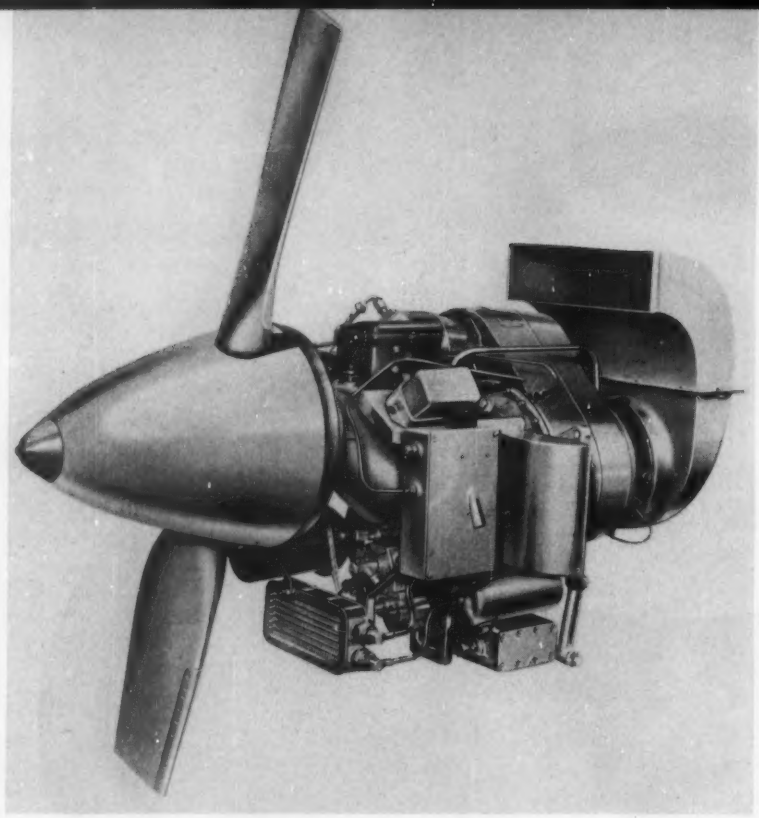


Smallest Turbo-prop Powers 'Currie Wot'

SOLIHULL, ENGLAND—Although the gas-turbine engine has yet to find its way into the family car, one automotive manufacturer has successfully developed it for small airplanes. Demonstrated last month in a British "Currie Wot" biplane, a 60 hp engine has taken over the title of world's smallest turbo-prop. Previously, the smallest was the French-made Turbomeca Bastan rated at 450 shp.

By-products of pioneer auto-turbine work by Rover Co. Ltd., the TP-60 and TP-90 engines (rated at 60 and 90 bhp) have similar external dimensions, weighing 235 lb and measuring 27½ in. high by 30 in. long (without propeller and spinner). Both models are the single-stage axial-flow type, and both are fitted with variable-pitch propellers (mechanically operated on the TP-60; hydraulically on the larger).

According to Rover engineers, the engines are vibration free, easy to maintain, and accessible for service. They can be installed as conversion power units on any light aircraft without major airframe modifications. Fuel can be either kerosene or diesel oil.

Topics

Conversations in the clouds—with people on the ground—should take place this summer, when American Telephone & Telegraph Co. hopes to install public telephones on commercial airplanes. Transmission of voices will be by radio between a plane and an earth-bound transmitting-receiving station; once on the ground, the call will be transmitted via regular telephone lines. Stations will be numerous enough and so placed as to permit contact with a plane anywhere over the U. S.

• • •

Easy go for the plaid-sport-coat set is made even easier by an electronic betting machine that lets a horse-racing fan place his bets without stirring from his seat. The machine, designed by Electronic Assistance Corp., accepts betting cards which the patron buys when he enters the track; wagers are placed by simply pressing buttons to indicate the horse's program number and the chosen finish position. The card serves as a receipt, and the data on it are also relayed to memory units for the calculation of odds and storage of information for possible pay-off. A drawback of this pushbutton system becomes apparent only if the wagerer wins: He has to walk to the cashier's window to collect.

• • •

A noise that tranquilizes a dental patient comes from a portable Sonic-Thesia unit, developed by Roberts Electronics Inc. Sonic Thesia is said to produce "dental analgesia" by means of stereophonic and white sound. By pushing buttons to select sound and volume, the patient keeps his mind off the dentist's activities with music or—to blot out pain—the beep of white sound.

• • •

Lugging home literature from a trade show will not be necessary at the IRE Convention and Show at the New York Coliseum. Lead-Master, a new digital-computer system developed by Data Patterns Inc., is being used instead to convey interests and names of attendees to exhibitors. A show visitor can leave his name at a booth, or request that literature be sent to him, without filling in a card.

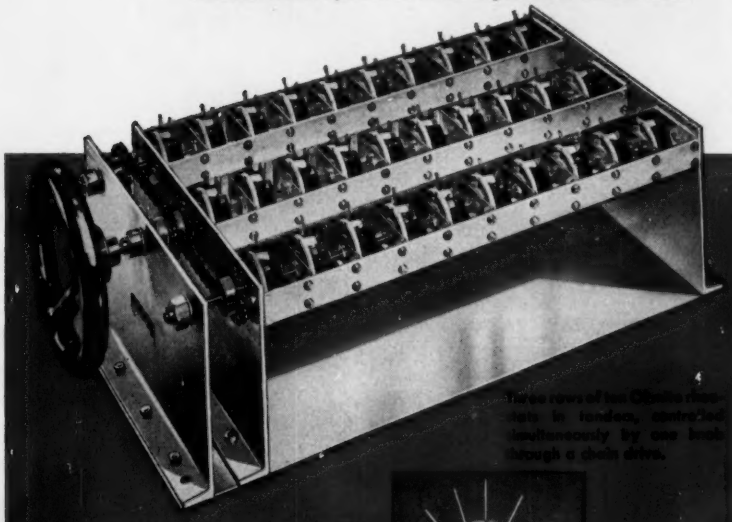
• • •

Two-ply tires, now on some compact cars, could be standard on 1962 models, and may even be used on a couple of standard-sized cars next year. Tire makers claim strength of the two-plies is as great as that of traditional four-ply tires, since they contain the same amount of fabric cord by weight. Advantages claimed are a softer ride and increased gas mileage (the tires run cooler, reducing rolling resistance).

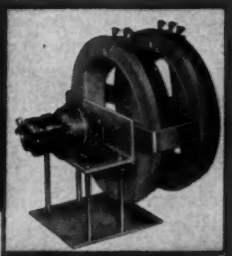
OHMITE
RHEOSTATS
WITH SPECIAL FEATURES
solve many difficult control problems

Ohmite offers not only industry's most complete line of *standard* rheostats but also rheostats with a wide variety of *special features*. Illustrated are only a few. All have the distinctive Ohmite design features: smoothly gliding metal-graphite brush; all-ceramic construction; insulated shaft and mounting; windings permanently locked in place by vitreous enamel. You will find the special rheostat feature you need in the dependable Ohmite line.

Two groups of four Ohmite taper-wound rheostats mounted in tandem, controlled by a single knob through a chain drive.

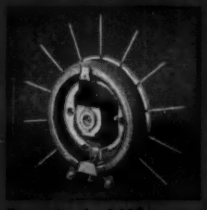


Three rows of ten Ohmite rheostats in tandem, controlled simultaneously by one knob through a chain drive.

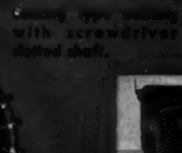


Type CU chain-driven tandem rheostat assembly.

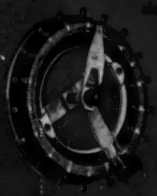
Ohmite rheostats can be mounted with two, three, or more in tandem for operation by one knob. Controls several circuits simultaneously. Model H and miniature Model Z rheostats in tandem with panel mount.



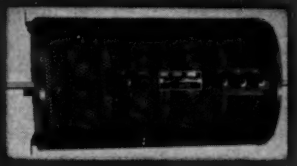
Example of a 360° rotation rheostat with a wire load tapped winding.



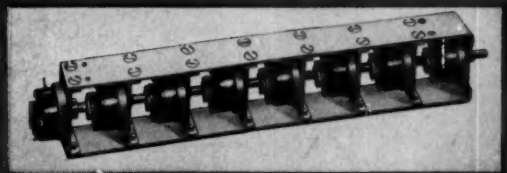
Rheostat with screwdriver slotted shaft.



Rheostat with tapped winding and switch, arranged to operate at any preselected position of control arm.



Ventilated types prevent mechanical injury, or human contact with electrically "live" parts.



Call on Ohmite for APPLICATION ENGINEERING SERVICE

Save valuable engineering time. Team up with Ohmite to solve your resistance problems. Ohmite engineers are resistance specialists. They can quickly analyze your needs and recommend the correct rheostat to fit your application.

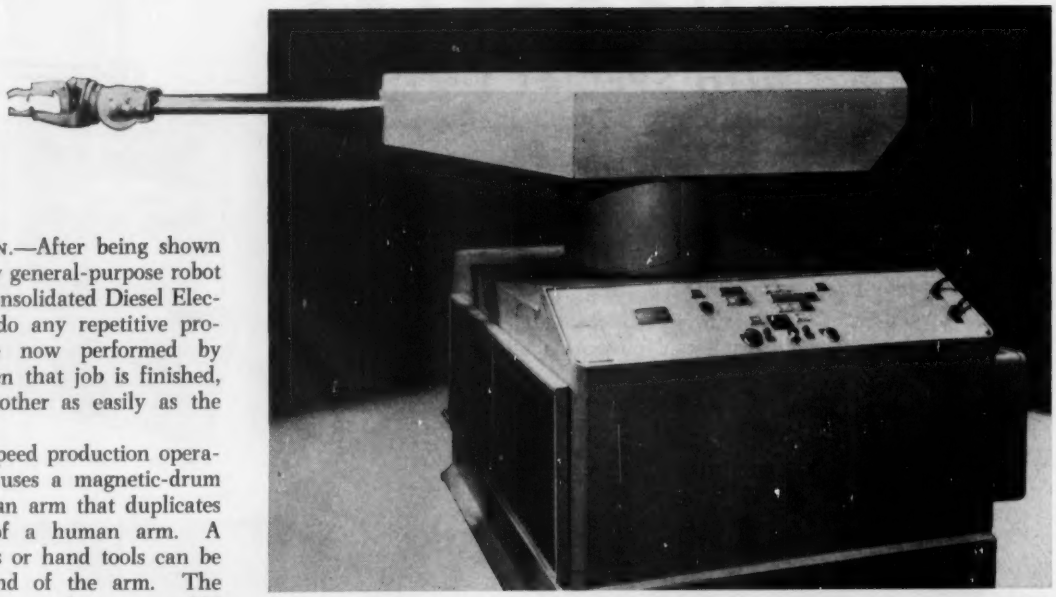
OHMITE

Write on company letterhead for Catalog 58.

OHMITE MANUFACTURING COMPANY
3618 Howard Street, Skokie, Illinois

RHEOSTATS RESISTORS TAP SWITCHES
RELAYS VARIABLE TRANSFORMERS DIODES
TANTALUM CAPACITORS R. F. CHOKES

Manipulator with a Memory



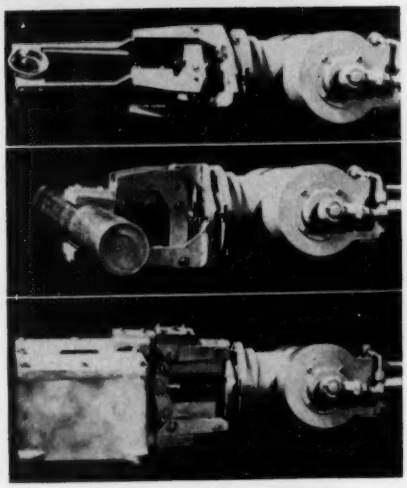
STAMFORD, CONN.—After being shown how once, a new general-purpose robot developed by Consolidated Diesel Electric Corp. can do any repetitive production routine now performed by man. And when that job is finished, it can learn another as easily as the first.

Designed to speed production operations, Unimate uses a magnetic-drum brain to direct an arm that duplicates the functions of a human arm. A variety of hands or hand tools can be fitted to the end of the arm. The brain, able to remember up to 200 sequential commands, learns to perform a task when a human teacher prods the hands to the desired position and pushes a record button. Thereafter, the manuevers are automatic until the teacher shows the machine a new set of movements.

Hydraulically operated, the arm telescopes in length from 3 to 7 ft, sweeping an arc of 220 degrees in a horizontal plane, 60 degrees vertically. All told, the robot can grasp objects within a sweep volume of 350 cu ft.

The wrist at the end of the arm both bends and rotates. The wrist joint terminates in a pneumatically operated hand or claw that can apply a wide range of grasping pressures.

Looking more like a gun turret than a production machine, Unimate has its brain boxed in its base. The base contains the control and operating mechanisms; there are no separately mounted peripheral devices.



Hands can be changed by removing two screws. Hands designed by CDEC include long, slender fingers to handle small or delicate parts, broad grippers to grasp heavy steel cylinders, and parallel jaws to assemble bulky objects.

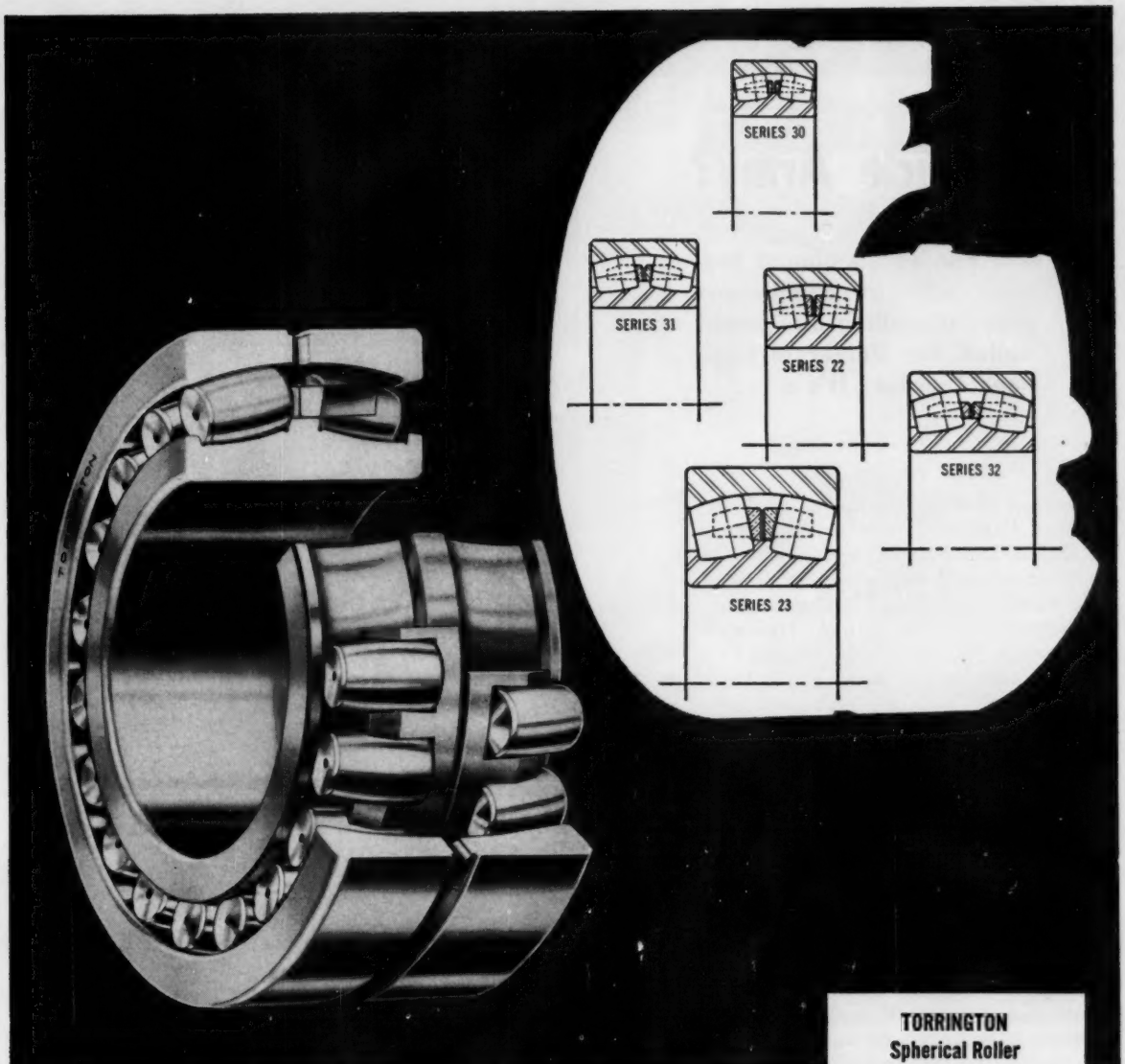
More Cash in the Colonies for Engineers

WASHINGTON, D. C.—Median salary of professional engineers in England today is less than half the figure that was reported by their U. S. counterparts for the year 1958. However, the median for English engineers is on the rise, jumping 32 per cent over the last four years.

The survey, reported recently by the National Society of Professional Engineers (U. S.), was conducted among 2727 members of the Institution of Civil, Mechanical, and Chemical Engineers. It reveals a median income of $4413 for the year ending April 5, 1960. For '58, the NSPE median was $10,000.

The table below shows results of the survey, with English salaries converted to dollars.

	Lower Quartile (dollars)		Median (dollars)		Upper Quartile (dollars)	
Age Group	1956	1960	1956	1960	1956	1960
Under 35	2352	3217	2678	3698	3119	4327
35-39	2712	3630	3209	4218	3867	5029
40-44	2922	3836	3600	4586	4662	5943
45-54	3231	3987	4170	4996	5620	6952
55-64	3417	4552	4642	5755	6477	8365
All ages	2670	3664	3319	4413	4496	5738



There's a Torrington Spherical Roller Bearing for your application

Bearings matched *exactly* to the job pay off in better performance, longer life, greater reliability. That's why it pays to specify carefully. And that's why it pays to choose Torrington Spherical Roller Bearings.

Whatever your space limitations or capacity requirements, the five series of Torrington Spherical Roller Bearings provide the right bearing for virtually every industrial application. You can design for straight bore or tapered bore with adapter. You can benefit from extra features such as lubrication groove and oil holes, or selected outside diameters.

Your use of Torrington Spherical Roller Bearings will assure exceptional operation and longer bearing life under the toughest conditions. They're made to Torrington's own uncompromising standards—the highest in the field of anti-friction engineering—by the manufacturer of every basic type of anti-friction bearing.

TORRINGTON Spherical Roller Bearings Offer:

- conformity of rollers to raceways
- integral center guide flange for stability
- positive roller guidance
- land-riding bronze cages
- maximum radial and thrust capacity
- controlled internal clearance
- electronically selected rollers
- inherent self-alignment
- even load distribution
- long, dependable service life

Send for new Torrington Spherical Roller Bearing Catalog #258

progress through precision **TORRINGTON BEARINGS**

THE TORRINGTON COMPANY South Bend 21, Indiana • Torrington, Conn.

Circle 410 on Page 19

One-Vehicle Army?

The concept is almost feasible with an unorthodox piece of rolling equipment called the Universal Engineer Tractor. It's a . . .

CHICAGO—Full-scale mobilization of Army's Corps of Engineers would muster approximately 2800 makes and models of rolling equipment. This defeats a current military-wide emphasis on "logistic simplification."

Designers at International Harvester's Construction Equipment Div., Melrose Park, Ill., think they have a solution to the Army's problem in the form of a high-speed prime mover called the UET (for Universal Engineer Tractor). UET is not only an earthmover and personnel-cargo carrier, it can mount weapons, crane booms, conveyor belts, winches, and earth augers. It is also amphibious.

Light Heavyweight

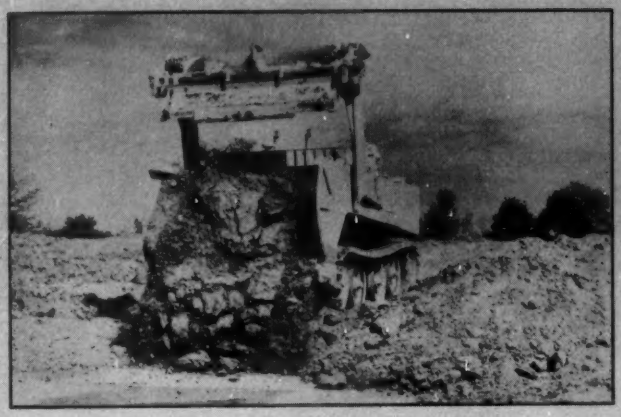
As a final design requirement, Army specified that UET should be air transportable and capable of parachute landings. By using plenty of aluminum, IH engineers kept the crawler's airborne weight to 20,000 lb. On the ground, the vehicle doubles its heft by taking on ballast, ends up with a maximum drawbar pull of 17½ tons—a respectable performance for a conventional tractor of twice UET's empty weight.

Bootstrap Suspension

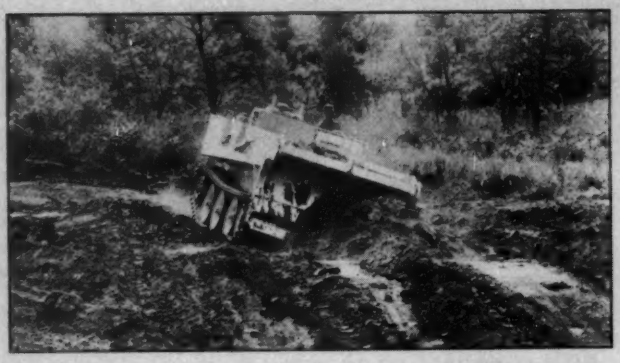
UET operates in a solid, unsprung state for earthmoving, but runs smoothly on and off highways at convoy speeds. A hydropneumatic suspension system meets the performance extremes.

Each of the eight wheels on the fully tracked vehicle is individually sprung by means of hydraulic rotary actuators and gas springs, called accumulators. When actuators are disconnected from accumulators, the tractor is unsprung for earthmoving. It can thus raise and lower itself "by its own bootstraps." The operator can nose it into the earth (by raising the front wheels) for dozing, raise it again to travel height by lowering the wheels. Height-correction

personnel carrier . . .



dump truck . . .



bulldozer . . .

. . . and it floats

valves in the suspension system keep the tractor level and at desired height under all loading conditions.

As a front loader, UET lifts a hydraulically controlled apron to open up its ballast bowl. Earth capacity is 7.4 cubic yards struck. A hydraulically operated gate in the bowl serves as an ejector, making it possible for the vehicle to spread its load on the go, or to dump with greater accuracy than a conventional dump truck.

The ejector gate also makes the UET a self-loader and unloader for cargo pods, palletized material, and even small vehicles. With the bowl floor lowered to ground level, cargo can be pulled in (by cable) or pushed out by the backward and forward motion of the gate.

Next: All-Oil Drive

The first UET prototype is powered by a 250-hp gasoline engine. A new version will be diesel powered through a hydrostatic drive. Steering, braking, and all forward and reverse motion will be controlled by a single control lever.

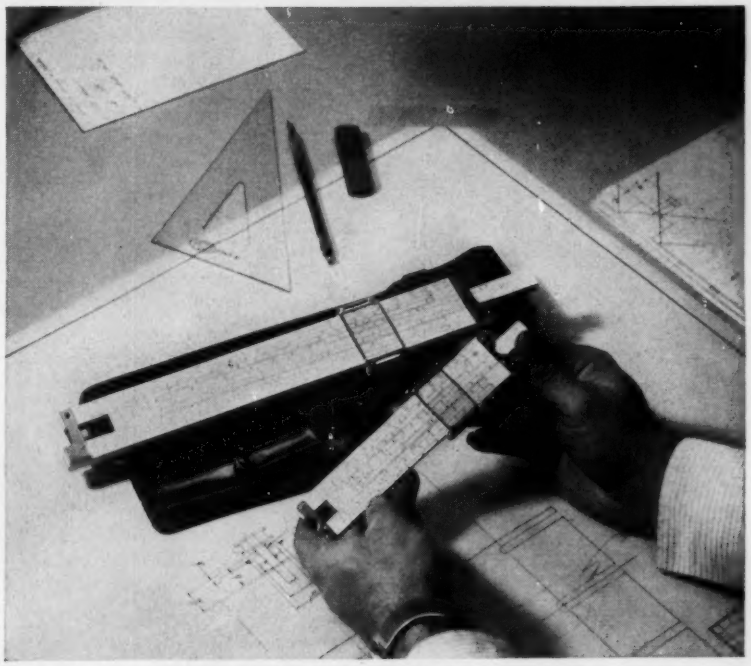
The prototype crawler is 220 in. long and about 84 in. high (with windshield folded down). It can pivot turn 180 degrees in a space 23 ft wide; operate ascending, descending, or side slope on grades of at least 60 per cent.

1 for 119

Military men estimate that UET could replace 119 makes and models of specialized conventional equipment now used by the Corps. This would reduce the spare-parts inventory for field operations from 161,160 to 2040 pieces. It would also reduce the number of skills required in a combat unit to man and maintain the equipment.

Engineers at U. S. Army Engineer Research and Development Laboratories, Ft. Belvoir, Va., estimate the production capability of UET to be 1½ to 4 times as great as basic earthmovers now in use. For example, they estimate that a fleet of six UET crawlers could handle 2000 cu yards of earth over a 2000-ft hauling distance in 4 hours. Six tractor-loader combinations in the present equipment line would require an estimated 10½ hours to do the same job.

DRAFTING TRENDS



This is a size comparison between the 10" POST Versalog and its 5" replica, the POST Pocket Versalog.

The trend to "COMPACT" slide rules

Why a small slide rule?

Users of America's best-selling POST Versalog, in the regulation 10" desk size, have been known to covet a 5" POST Pocket Versalog, and even buy one . . . as a more easily carried convenience . . . as a spare . . . or just for the sheer joy of having, like a gun collector, a "matched pair."

It took more than requests from pleased users of the 10" Versalog to convince our marketing people that the need actually existed for a premium-priced 5" pocket rule with 23 scales. Our technical men were even harder to convince that high Versalog standards of accuracy could be maintained in miniature.

Who can use them?

That there is a need has since been proved by the thousands of engineers, architects, scientists, and students who have bought and used a POST Pocket Versalog in preference not only to the larger version, but after comparing it with other smaller makes.

As to accuracy, we are still amazed at the exquisite job our production team has done in miniaturization—the 5" Pocket Versalog includes every one of the 23 scales found on its much larger counterpart and, in addition, bears engine-divided calibrations of such sharpness and clarity that no magnifier is needed.

Own a Versalog for less

To further popularize this fine instrument, POST dealers are offering it at a special low price for a limited time. All models come with a handcrafted leather case and spring pocket clip. Also available with hardbound instruction text.

For further information, ask your POST dealer. Or, for free literature, price data and name of nearest dealer, write to Frederick Post Company, 3652 North Avondale Avenue, Chicago 18, Illinois.

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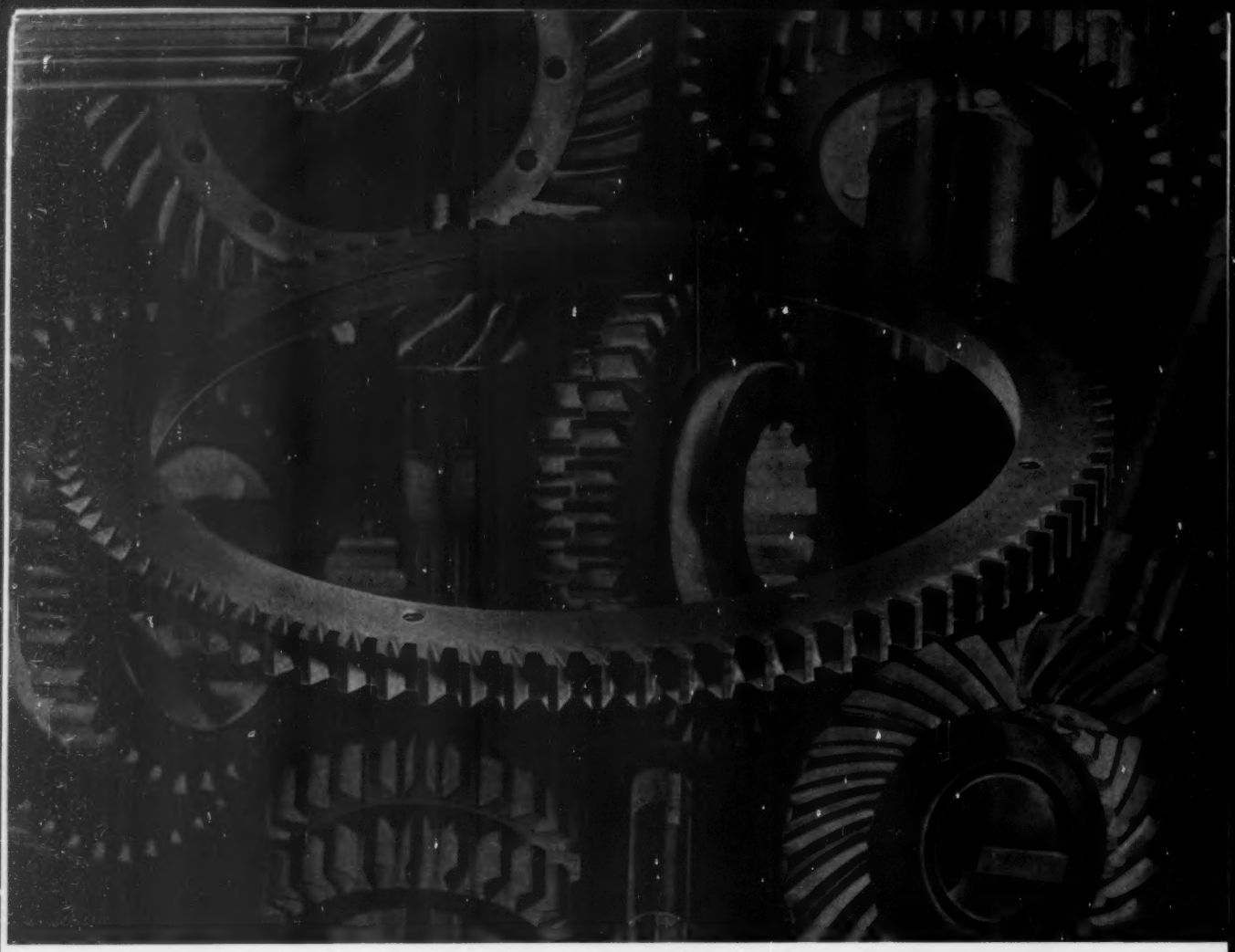
ENGINEERING EQUIPMENT & DRAFTING SUPPLIES • FIELD EQUIPMENT & DRAFTING FURNITURE



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and remember all **DOUBLE DIAMOND GEARS**

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GEARS FOR AUTOMOTIVE, FARM EQUIPMENT AND GENERAL INDUSTRIAL APPLICATIONS
GEAR-MAKERS TO LEADING MANUFACTURERS

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Reader Information Service

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USE A YELLOW CARD
for More Information . . .

CIRCLE ITEM NUMBERS—Throughout the magazine, each advertisement carries an Item Number for use in requesting further information. All product descriptions, announcements and Helpful Literature items are also numbered, and for greater convenience are indexed below by Item Numbers.

EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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Miniature Power Supply	788
Terminal Kit	789

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425	455	485	515	545	575	605	635	665	695	725	755	785	815	845	875
426	456	486	516	546	576	606	636	666	696	726	756	786	816	846	876
427	457	487	517	547	577	607	637	667	697	727	757	787	817	847	877
428	458	488	518	548	578	608	638	668	698	728	758	788	818	848	878
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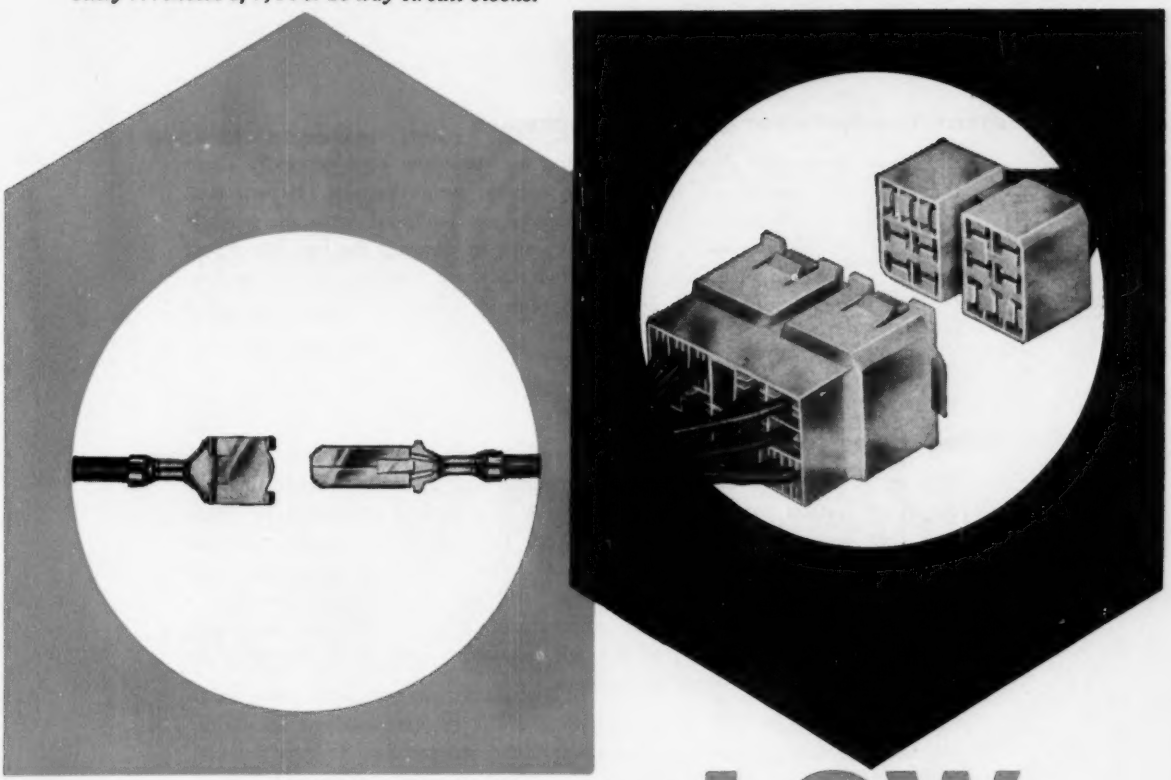
20-25 amperage rating for greater design flexibility . . . choice of 7, 14 or 20 way circuit blocks.



LOW

2-5 pounds insertion and extraction force for easier installation and servicing.

NEW AMPEEZ CONNECTOR GIVES YOU BOTH

Here is a workhorse of a connector! Housed in tough nylon and designed to carry as many as 20-circuits while holding insertion-extraction forces to 2-5 pounds, AMPEEZ Connectors are adaptable to many applications calling for a heavy-duty, easily serviced multiple-circuit disconnect.

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Circle 413 on Page 19

attractive footwear a must for spacemen

Air Force researchers developing clothing for spacemen now generally agree that magnetic sandals are necessary to combat weightlessness. Experiments with zero-g conditions indicate test subjects not equipped with the sandals lose their spatial orientation. In contrast, airmen wearing the footgear report "down is where my feet are," even when they are standing on the ceiling. Up-down orientation should be a basic consideration in design of a space vehicle, the AF report concludes.

Teflon takes to plating

The entire range of electroformable metals, both base and noble, can be plated on Teflon parts of any shape in a new process developed by Plasitron Inc., New York. Tests made by York Research Corp. showed complete adhesion of the metal, with no loss of Teflon's electrical properties. Soft soldering can be done without damage, and the soldered joint becomes a hermetic seal at a wide range of temperatures. Plated Teflon has been used in dielectric wave guides, feed-through insulators, and flush antennas for missiles, eliminating the need for radomes.

lag in plowshare technology

A workable inspection system is not available in the event that the U. S. and Russia reach an agreement on disarmament. "We have a minor amount of machinery to improvise the job," says Dr. Eugene Fubini of General Electric's Airborne Instruments Laboratory, "but we are far behind in arms-control technology." This was one conclusion reached in a recent panel discussion held for GE by seven arms-control experts. Cost of designing inspection equipment is relatively small, but installation and operation may cost many billions of dollars. Two major items are hardware for detecting nuclear explosions underground or in outer space, and provision for world-wide communication and data analysis.

NSPE nixes NSA

Establishment of a National Science Academy like the one outlined in legislation now before Congress could prove to be the most expensive and least effective method for improving the nation's supply of engineers. This is the opinion of the National Society of Professional Engineers. According to Paul H. Robbins, NSPE's executive director, the Federal Government does not need to spend time, effort, and money for education of engineers. The universities are presently capable of handling considerably more engineering and science students at both undergraduate and graduate levels.

nuclear-seapower prices drop

After taking another look at the economics of nuclear-powered ships, the Navy has decided they don't compare badly with the oil burners after all. Earlier estimates of initial plus operating costs showed the ratio to be 3:1 in favor of conventionally powered ships. Now, thanks to better nuclear fuels and a little operating experience, the ratio is down to 3:2. Biggest single factor appears to be an upgraded life expectancy of nuclear fuel cores (from two years to five).

more red literature heads west

Co-operation between U. S. and Western European engineers and scientists will lead to wider distribution of Soviet-bloc technical literature, translated into English, French, German, or similar languages usable by both Americans and Western Europeans. A European Translation Center has been established at the Technical University at Delft, Netherlands. It is being assisted by and will use the same classification systems as the Office of Technical Services, U. S. Dept. of Commerce, which has been collecting and distributing translations and information on translations for several years. *Technical Translations*, published semimonthly by OTS, now lists about 500 translations in each issue; swapping information with the European agency should eventually double this number.

thin-film tunneling without supercooling

A thin-film diode that tunnels without the cryogenic assist, usually required by such a device, is reported by Republic Aviation Corp. Researchers at Republic build a thin-film microcircuitry sandwich by capturing titanium vapor on a strip of glass to form a dielectric coating—less than one-millionth of an inch thick—through which electrons can tunnel. Although still an experimental item, this room-temperature diode promises simplified microminiaturization of electronic circuits. In use, it could shrink equipment such as room-sized computers to table-top dimensions.

Russians push multilayer coatings

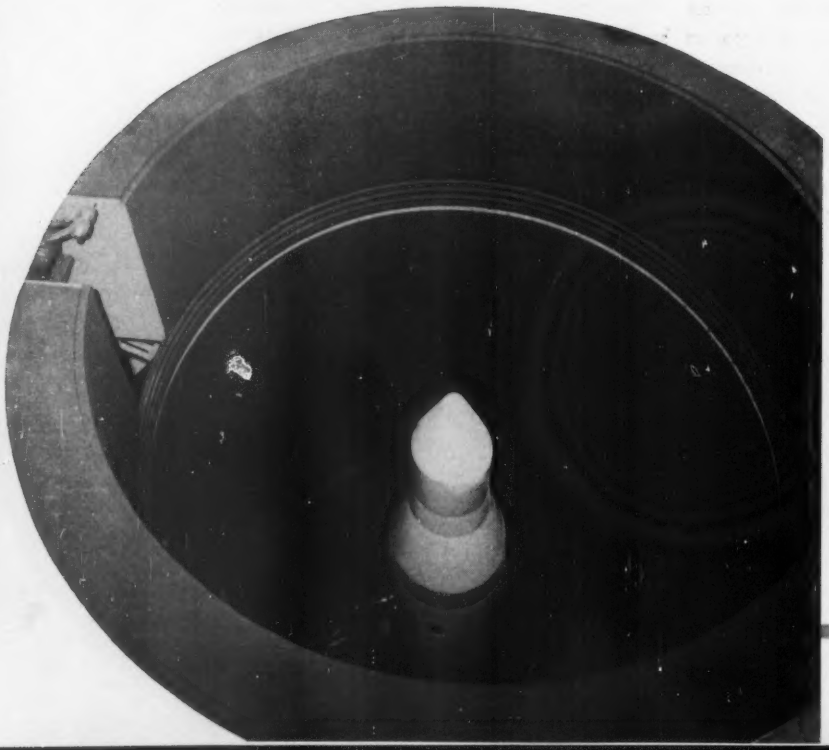
According to reports from the USSR's Academy of Sciences, the best way to protect iron and steel surfaces from high-temperature oxidation is to apply diffusion coatings of various protective metals in separate layers. The multilayers are claimed to be much more effective than a single coating consisting of a mixture of metals. Benefits of multilayers are tied in with the chief advantage of diffuse coatings—their stronger bond to the ground metal, actually penetrating into the crystal lattice.

Minuteman

AIR Force's second-generation ICBM, the Minuteman, breaks an age-old tradition in the design and production of weapons: It costs less than its predecessors. The price of one Minuteman, on target, is estimated to be about 1/10 that of an Atlas or Titan.

Despite the economy, Minuteman represents little in the way of performance sacrifice. Its 6300-mile range is less than the 8000 to 10,000-mile reach of big liquid-fuel missiles, and it carries a smaller warhead. But both these matters are somewhat academic, since Minuteman will cover all major targets of our immediate enemy, and its warhead has several times the destructive power of the devices dropped on Hiroshima.

Solid fuel gives the new ICBM its biggest advantage—the missile requires practically no care and feeding. A whole squadron of Minutemen, standing dormant in silos, can be monitored and activated by a relatively few men at distant control consoles. A single Atlas or Titan requires a battalion of technicians and a tangle of equipment.



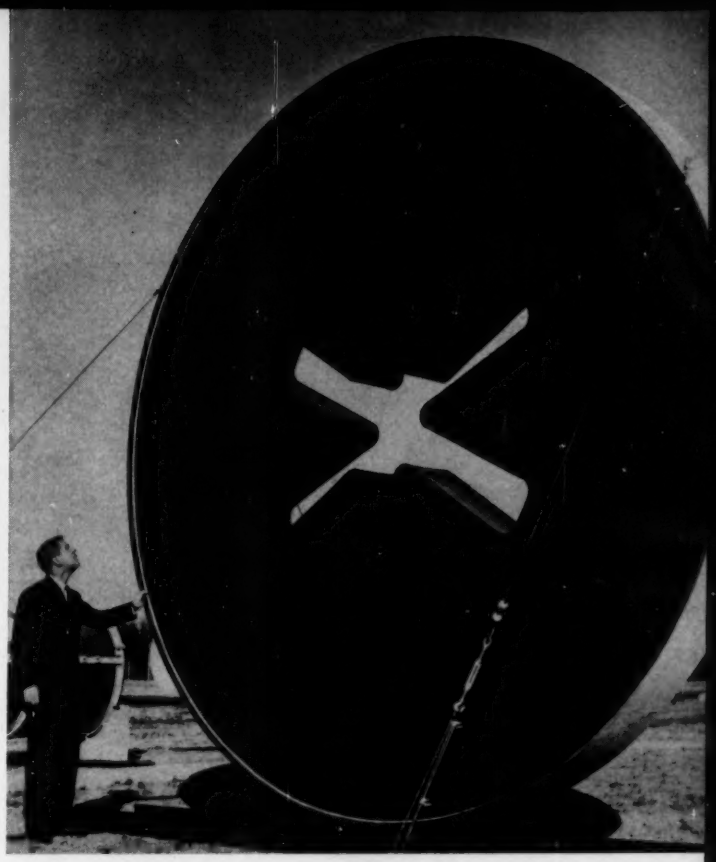
Countdown-ready Minutemen, deployed in well-spaced squadrons of 50, will be ready for almost immediate action. Missiles are fired directly from underground silos, rather than first being ejected (Polaris) or elevated to the surface (Titan). The concept of silo firing raised serious theoretical problems—potential damage to the missile from hot exhaust gases, noise vibration, etc., indicated that complex vented (U-shaped) silos might be required. Tests quickly proved that a simple hole in the ground would suffice. Result has been a vast simplification in launch procedure, economy in construction.

Boeing's bargain-basement entry in the missile buildup may trigger a demand for big solid-fuel space boosters

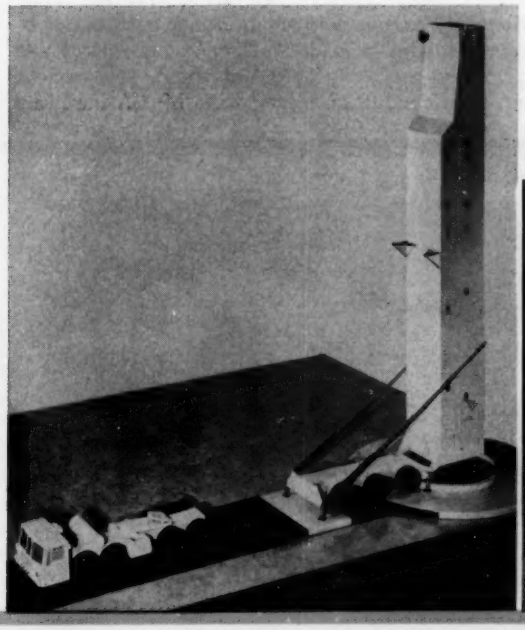
Mobility, Minuteman's other major attribute, is almost an integral part of the missile. Each of its three stages leaves the factory cradled in a special shock-absorbing carriage which rides on two inverted V rails. The rails are built into truck vans, factory trailers, storage depots, and assembly lines. On all of this equipment, the rails are at a constant height above ground permitting quick transfer of the missile or its stages.

In mid-1963, Minuteman will really take to the rails . . . in the first of perhaps 100 missile-launching trains. Each train, composed of a dozen or more cars, will carry up to five missiles in special 88-ft launch cars. Missiles will be contained in strongbacks—a two-piece package, containing heating and ventilating systems, that folds back pedal-fashion after the missile has been erected. Blast deflectors, built into the floor of the car, will minimize damage to the car and permit its reuse after refitting.

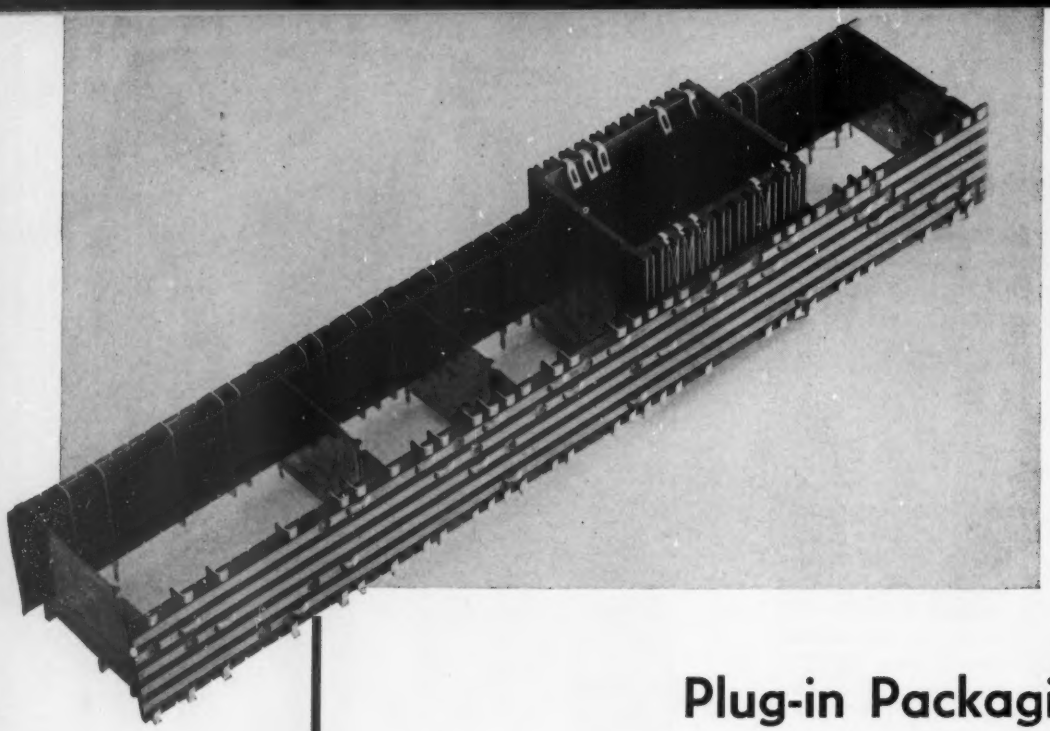
First silo-based Minuteman squadron is scheduled to be operational in mid-1962.



Solid-fuel motor developing 2.4 million lb thrust can be built with existing technology, according to Thiokol Chemical Corp. Motor would be 63 ft long, 14 ft in diameter (cross section, above). For space work, Thiokol proposes clustering seven of the motors into a 43-ft diameter booster that would develop almost 17 million lb thrust. Three of the motors would be used as the second stage of a multi-stage vehicle which the company says could be built within three years. Largest liquid-fuel booster that will be available within this period is the Saturn, a cluster of eight engines, which will develop approximately 1.5 million lb thrust.



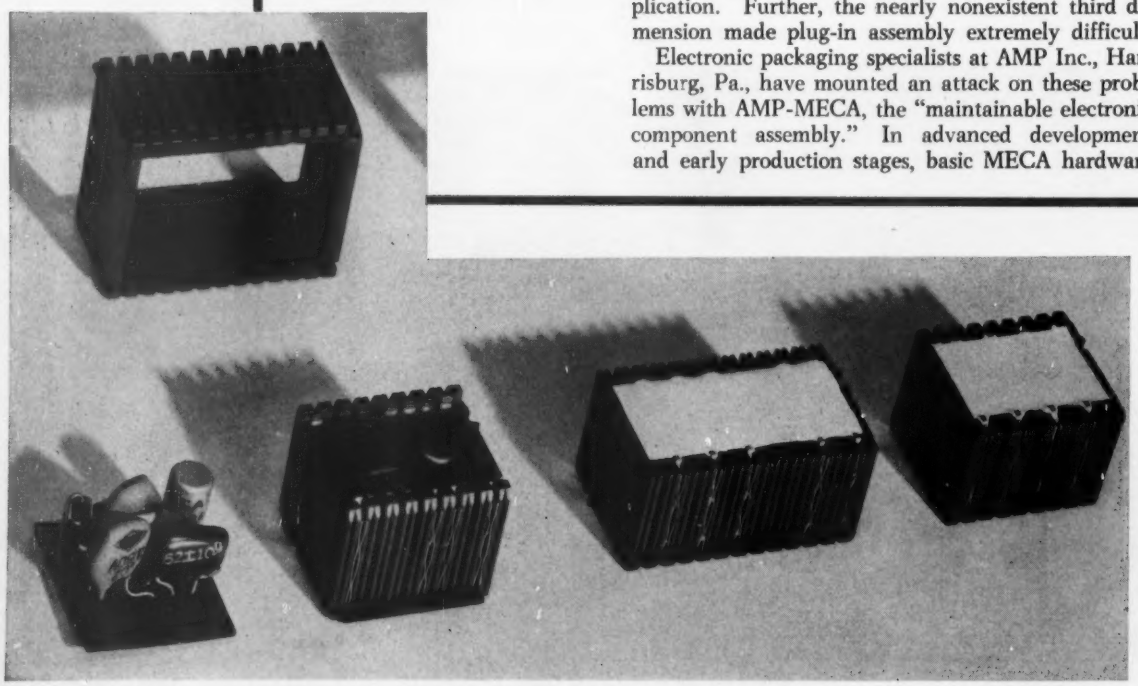
Transporter-erector will carry Minutemen from the assembly plant to launch sites and lower the missiles into silos. Vehicle is designed for highway travel, but the trailer, with missile, can be detached for piggyback travel on railroad cars and is also air transportable. Tractor and undercarriage, designed by GM's Truck and Coach Div., are air suspended; powerplant is GM's 275-hp V-12.



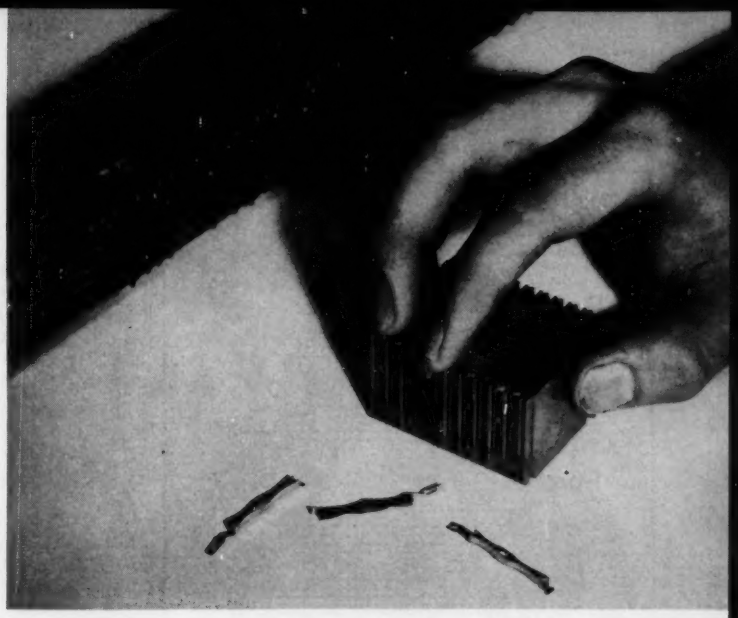
Plug-in Packaging for

TROUBLE in electronic circuitry begins too often when the designer adds the third dimension. The traditional development path, leading from paper-and-pencil schematic to punched-steel chassis assembly, produced three-dimensional structures ill-suited to cope with today's tight specifications on reliability, component density, weight, and maintainability. And even with more advanced techniques, two-dimensional printed-circuit boards —usually overlaid with a hodge-podge of odd-sized, poorly supported components—often failed under the stresses, flexures, and shock of an advanced application. Further, the nearly nonexistent third dimension made plug-in assembly extremely difficult.

Electronic packaging specialists at AMP Inc., Harrisburg, Pa., have mounted an attack on these problems with AMP-MECA, the "maintainable electronic component assembly." In advanced development and early production stages, basic MECA hardware



Electronic maintenance is expensive—occasionally ten times the first cost. Until reliability reaches 100 per cent, designers can attack the problem by packaging for plug-in substitution of faulty functions.



Throw-away Electronics

(top, left) consists of a modular series of plug-in shells, plus "expandable" mating connectors. Design aim was to provide a universal packaging assembly with high strength in three planes, integral wiring paths, and the capability for fast correction of faults by substitution maintenance.

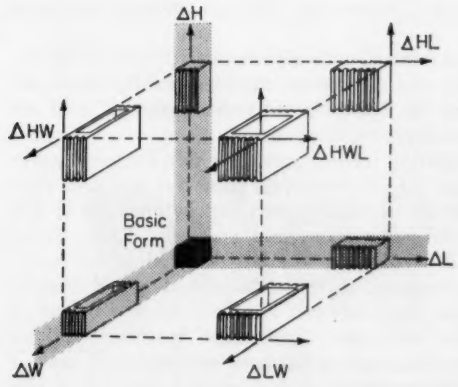
AMP stresses that the new development is not, in itself, another "electronic breakthrough." Rather, it's a packaging system designed to be completely compatible with present-day conventional or solid-state subfunctions and will adapt easily to foreseeable future advances—in molecular or thin-film electronics, for example.

3-D Protection from a Prism

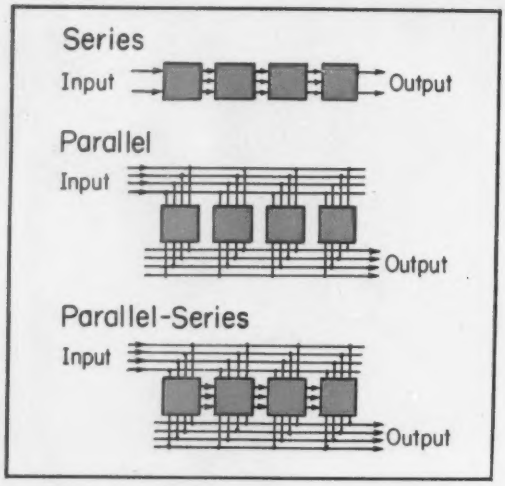
Basic building block in MECA is the hollow cell which will encapsulate electronic components, functions, or multifunctions. Although made to a basic form, cells are not fixed in physical size. Heights, widths, and lengths can vary through a wide range on either 0.1-in. or 0.2-in. grid systems. This flexibility, says the developer, permits the circuit designer to package in a single cell only those components or functions that constitute an economically expendable module—that is, it permits "throw-away" maintenance.

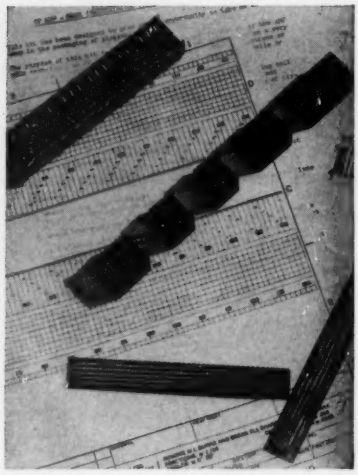
The standard cell is formed with a bottom which allows it to act as its own encapsulating mold. Where repairability of single components making up a single function is required, the bottom of the cell can be left open. Material for a standard compression-molded cell is glass-filled diallyl phthalate, although it can be furnished in any other insulating material that can be machined, cast, or molded.

Slots on opposite sides of module cells (above) accommodate and protect resilient and redundant spring contacts. Depending upon the circuit arrangement, (series or parallel), spring contacts either

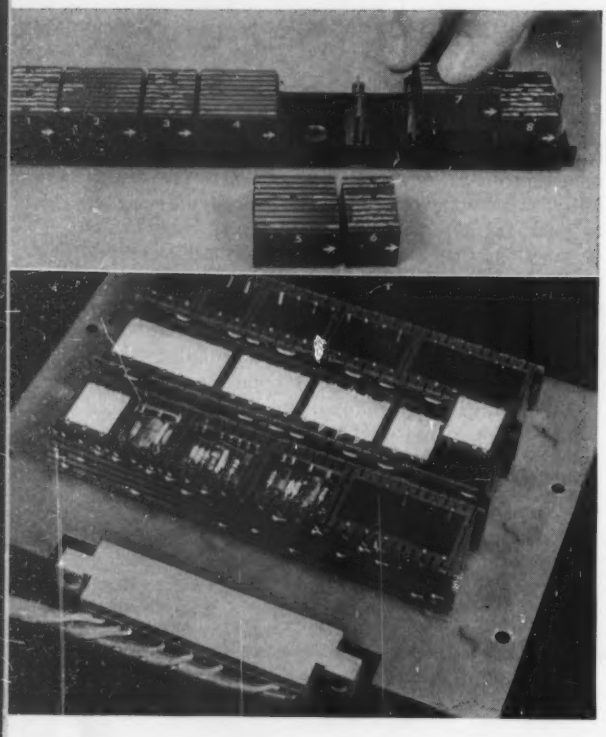


Plug-in modules, designed to be compatible with present-day or future electronic functions (far left), permit quick testing of components during production assembly or circuit operation. Incremental variations of the basic form (left) gives circuit packagers a choice of cell lengths, widths, and heights on either 0.1-in. or 0.2-in. grid systems.





Wiring - program charts simplify preparation of MECA parallel-circuit layout. Standard symbols indicate printed-circuit conductors, soldered connections, interruptions, spacers, module cells and contacts.



Interconnections for modular cells—and resulting complexity of programmed circuitry—depend on the circuit arrangement desired (sketch, top). Simplest is the pure series circuit, which requires no programmed boards. Each cell-encapsulated function is connected to the next in orderly succession (middle photo), with inputs entering one end and outputs leaving the other. In parallel-circuit applications, module contacts face parallel programmed-circuit boards on both sides of the assembly. Where the arrangement is parallel-series (lower photo), "strings" of cells can be mounted on a common printed-circuit base. Parallel connections are made through rib contacts and horizontal parallel-circuit conductors; interassembly connections, inputs and outputs are made through baseboard circuits.

mate with those on adjacent cells through shorting bars, or engage nonstressed ribs on the receptacle connector, the second major element of MECA.

In the Connector: Built-in Circuits

Length of the receptacle connector—which establishes between-cell circuits in parallel arrangements—depends on the number of cells in a string. Made up of opposing copper-clad boards (single-side cladding), the connector matches the cells in height. Parallel conductor paths are formed by removing copper cladding to the grid desired (for example, 0.1-in. spacing between conductor centerlines).

Rib tines required by a parallel-wiring program extend through drilled holes in the circuit board, where they are clinched prior to soldering to conductor paths. All other tines are removed, except top and bottom tabs which mechanically secure each rib to the circuit board. Assembled with spacers at each cell location, the boards form a two-sided matrix connection between parallel cells in a string.

Programmed circuit boards are eliminated when a series-connected string of module cells is desired. All circuits are arranged so that contacts on one cell face adjacent contacts on the next; shorting bars, mounted upright on a base chassis, connect cells in a string. Feedbacks can be made through the cells themselves, or carried through printed-conductor boards.

By combining both techniques (programmed circuits and shorting bars), complex parallel-series circuits can be built up with the basic cell and receptacle-connector hardware.

Anticipating further growth of thin-film and wafer functions, MECA developers point out that such two-dimensional circuit elements can be enclosed in flat cells with contacts on only one side. Tabs can be mounted on top or bottom of the module (or both) for interconnection through printed-circuit boards. The same procedure can also be utilized with any of the new solid-state, molecular functions. Where micro-miniaturization has been accomplished, several can be interconnected and encapsulated in a size more compatible with the MECA structure.

greatest capacity for the UNKNOWN

SHAFER-REX
Self-Aligning
Roller Bearing

When you specify a bearing, you can't tell how long it will last beyond its rated load capacity and normal service life.

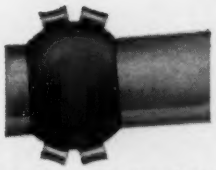
Nor do you know whether neglect or severe conditions might cut bearing life short—resulting in customer dissatisfaction, justifiable or not.

Yet, the reputation of your equipment might depend on how the bearing meets the unexpected.

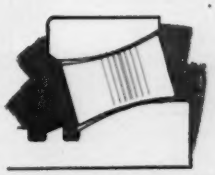
The safest way is to specify the bearing that meets the most critical requirements for maximum bearing life—the Shafer-Rex Self-Aligning Roller Bearing.

For full information, write CHAIN Belt Company, 4643 W. Greenfield Ave., Milwaukee 1, Wis. In Canada: Rex Chainbelt (Canada) Ltd., Toronto and Montreal.

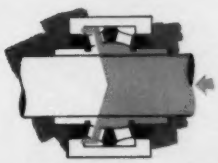
SHAFER® REX® SELF-ALIGNING ROLLER BEARINGS



Shafer-Rex design eliminates additional wear and stress caused by misalignment. Due to the ball-and-socket interaction between the inner race and rollers, misalignment is accommodated by the inner race—it never reaches the rollers. Whether the load is misaligned or not, rollers never tip. They remain in the aligned position, assuring equal load distribution through the center of each roller at all times.



Shafer-Rex design takes severe shock and loading safely. Rollers are concave; raceways are convex with a slightly smaller radius. This allows minimum contact between roller and raceway surfaces under normal loads. Under shock or heavy loads, this design permits the bearing surfaces to compress safely, increasing the load-bearing area to meet excessive load requirements without damage or excessive wear.



Shafer-Rex design takes thrust loads without strain or binding. Shafer-Rex Concave Rollers are self-centering. This, combined with ball-socket design, allows the most severe thrust loads or radial-thrust loads to remain safely centered on the rollers —eliminating roller end-wear—eliminating the need for a guide flange, a common source of wear.

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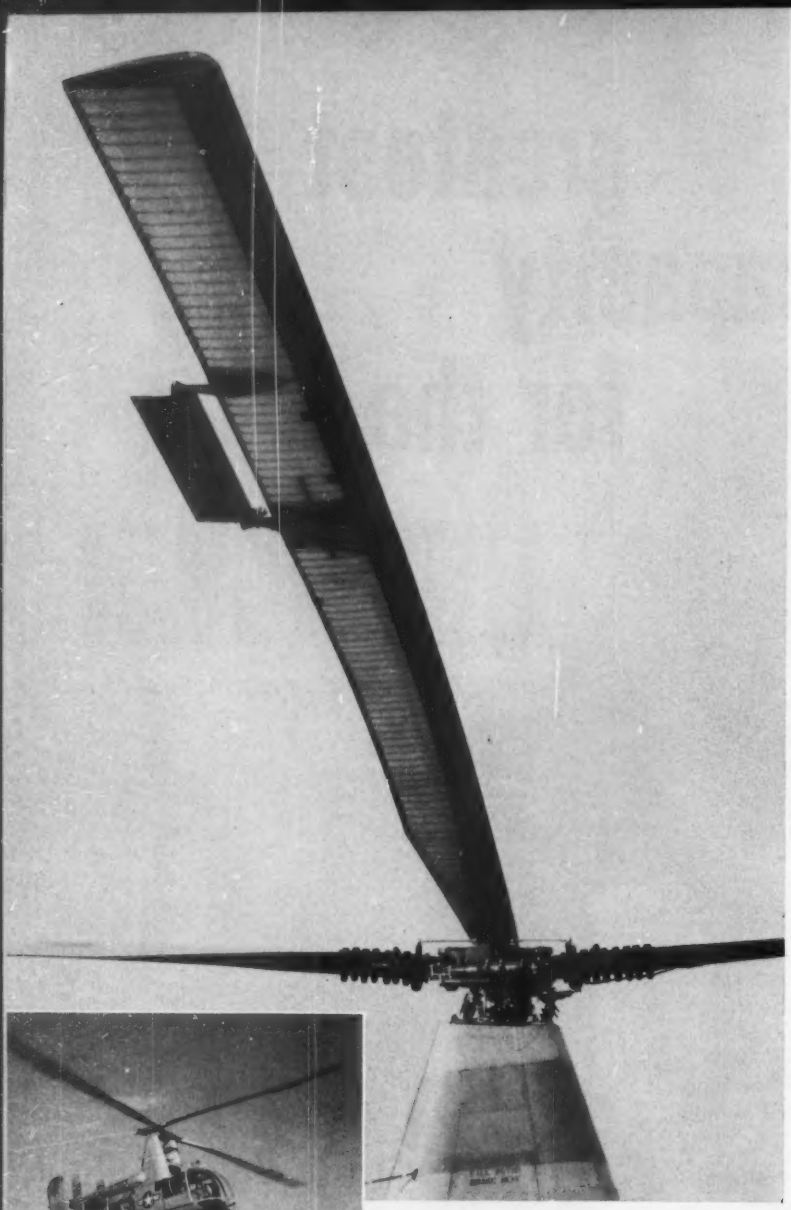
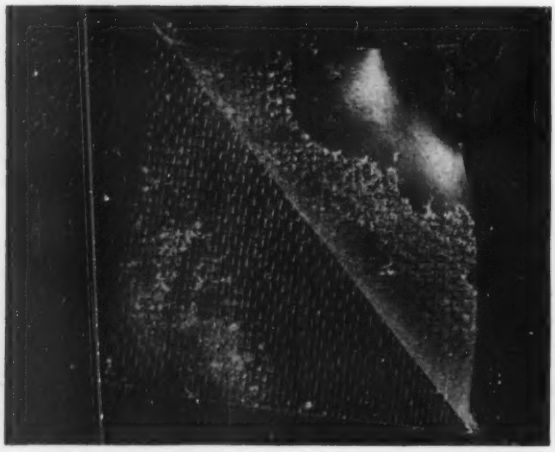
ENGINEERING NEWS

PICTURE REPORT

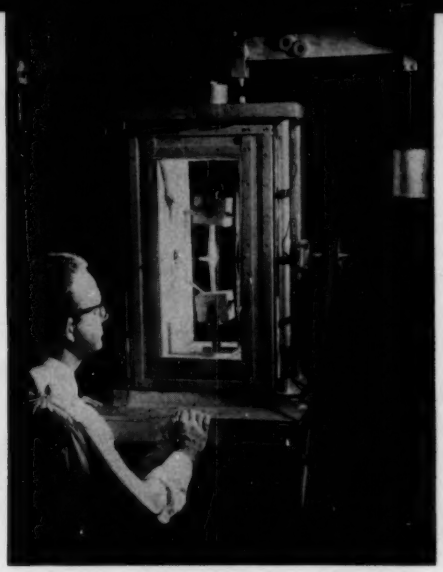


Glass-fiber rotor blades performed as well as wooden or metal ones during their first flight on a Kaman H-43 helicopter. This use of glass fiber improves rotor-blade fatigue resistance and also makes possible major savings in manufacturing and maintenance costs, according to Kaman Aircraft Corp. Prior to use of glass fiber for entire blades, high-stress areas (e.g., leading edges) on conventional blades had been strengthened with the material.



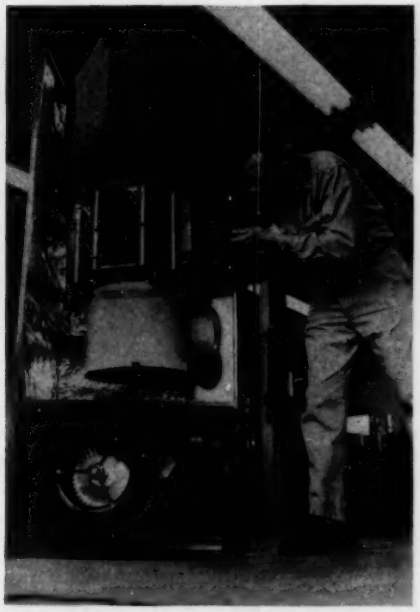
Wire mesh reinforces a fabric designed to foil vandals who would carve the upholstery of public vehicles. The mesh is sealed between two layers of vinyl plastic to make an exceptionally durable fabric. The metal and plastic sandwich was developed as an experimental product by American Steel and Wire Co.

Shooting the breeze with infrared radiation assures a private conversation between two people at distances up to three miles. This "ray gun" converts spoken words into infrared beams; to receive, it reverses the procedure. The Maxsecom (Maximum Security Communications) system, announced by the Aeronautical Div. of Minneapolis-Honeywell, uses a portion of the electromagnetic spectrum that is considerably less crowded and, therefore, less subject to public control than radio channels. Immunity to interference, detection, and jamming makes Maxsecom a useful tool for military and police work. A larger version has a range of 20 miles.



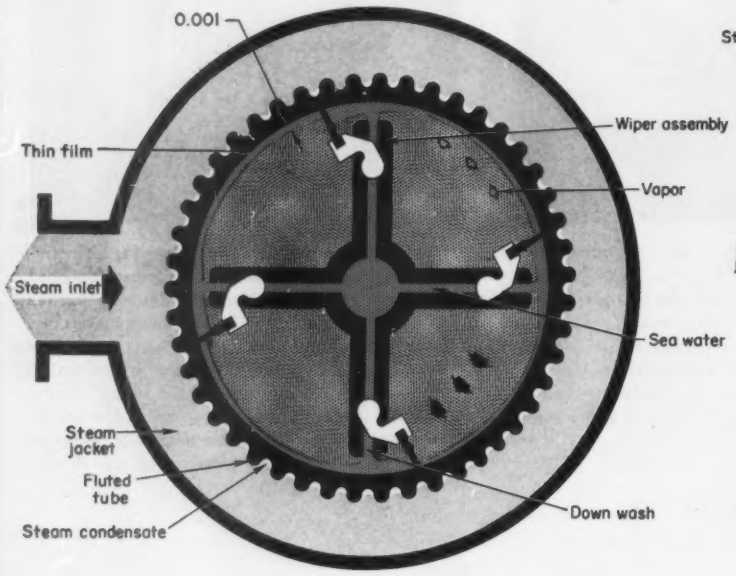
Checking column-failure calculations for high temperatures is possible with this equipment designed and built at Battelle Memorial Institute for the U. S. Air Force Aeronautical Research Laboratory. Stiffness of columns under conditions encountered by aircraft and missile structures is predictable with the new method of analysis, which is based on short-time stress-strain properties of materials. Previously, it was impossible to predict properties of a column in which metal creep caused continual changes in shape.

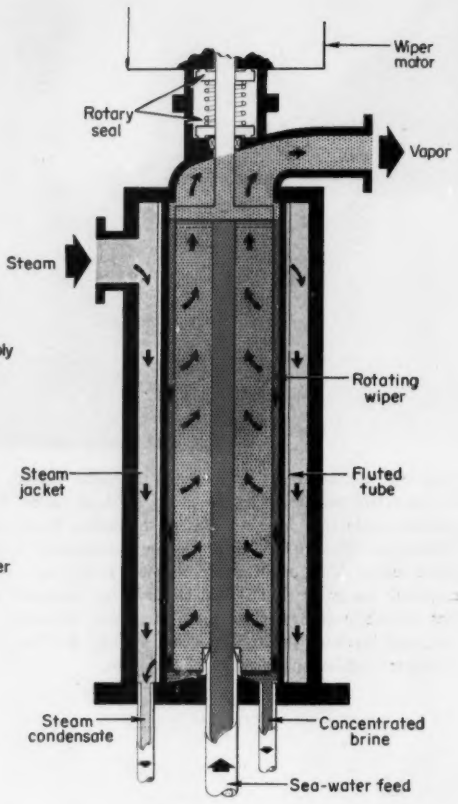
Fuel cells are being mass-produced by Allis-Chalmers Mfg. Co. for educational purposes. The Fuelectric kit consists of the cell itself (housing and electrode plates) and a 1½ to 3-v dc motor with leads and a propeller. Assembly instructions tell the student what chemicals are required and how they should be measured and mixed. The kit is available to science classes for $9.75 from Allis-Chalmers, Milwaukee 1, Wis.



Gas and thermoelectricity mix in a forced-air furnace whose blower is powered by a 130-w generator which converts heat from the burning gas directly into electricity. A big advantage, according to furnace maker C. A. Olsen Mfg. Co., is the uniform air temperature provided by the gradual increase in blower speed as the power from the generator builds up. The generator consists of four 8¼ by 4¼ by 2½ in. modules placed around the combustion chamber of the furnace.

Water films are only 0.001 in. thick in GE's radical new seawater purifier. Rotating wipers and a fluted heat-transfer surface push efficiency beyond that attained by other distillation units designed for saline-water conversion.





From 100 lb of brine, 42 lb of fresh water. Thin films do it in a

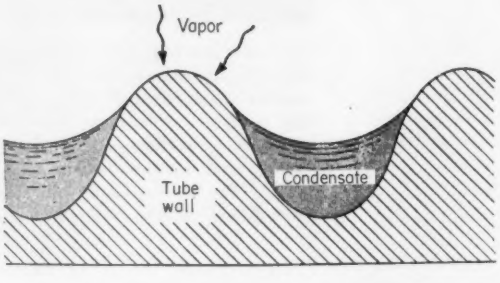
Wiper-Blade Heat Exchanger

SCHENECTADY, N. Y. — Rotating wiper blades and a fluted heat-transfer surface have sparked a new approach to design of distillation-type saline-water purifiers. Tests just completed on a General Electric Co. prototype lead engineers to predict the radical new equipment will offer 60 per cent space and 40 per cent weight savings.

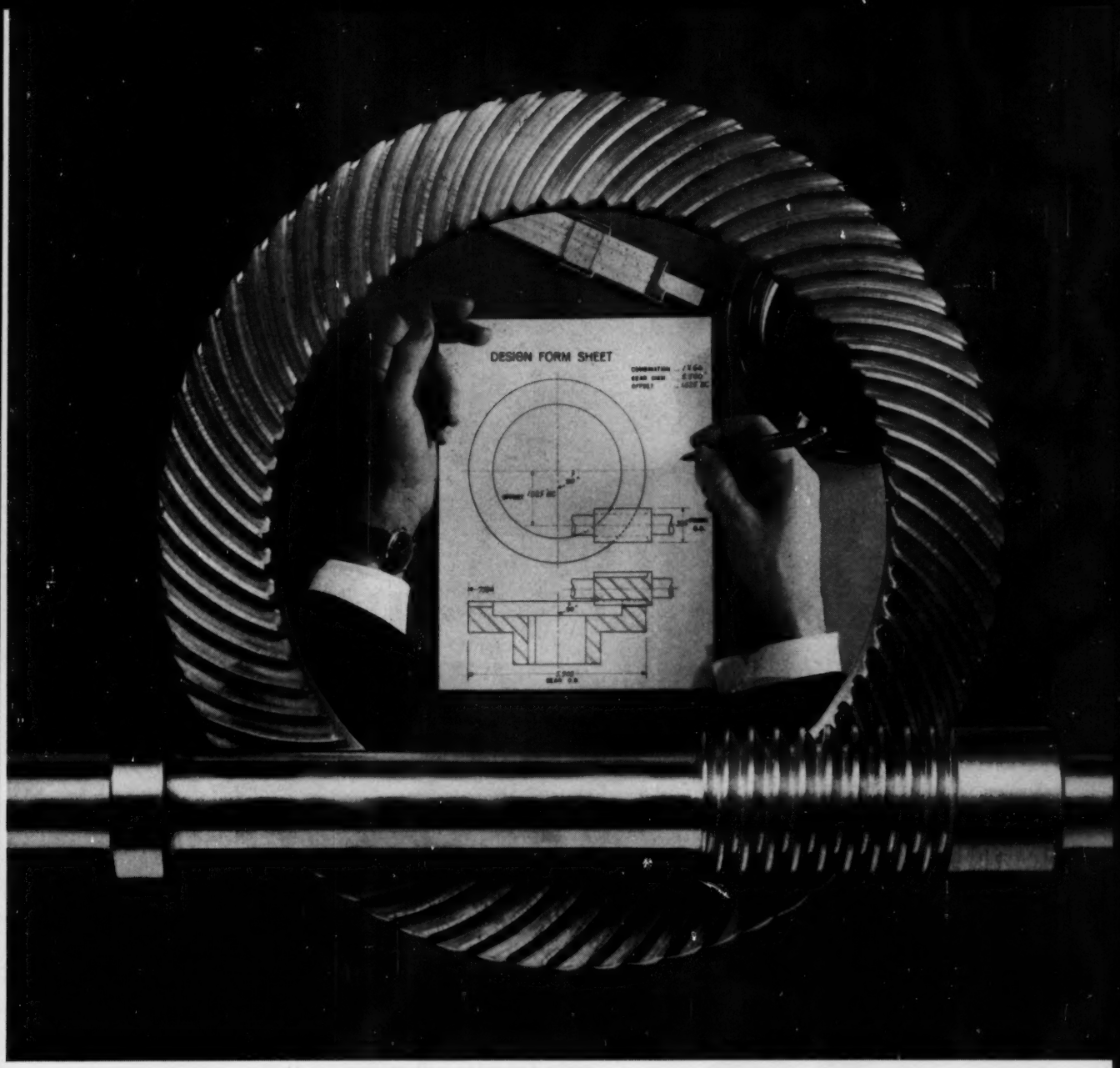
Spinning at 200 rpm, the blades spread brackish-water films on the inside wall of an evaporator. By restricting film thickness, they keep the water layer too thin to support bubble formation, allowing pure vapor to be evaporated. The fluted surface increases the unit's heat-transfer coefficient to a level at least four times higher than that achieved by any distillation purifier now on the market, according to GE.

The evaporator tube, mounted in a steam jacket, produces 42 lb of fresh water from every 100 lb input. Saline water, injected and sprayed through the blade assembly, is wiped ahead as it flows down the inside wall, leaving behind a 0.001-in. film. Bubble-free evaporation of the film creates fresh water of exceptionally high purity (about one part salt per million parts water) by avoiding carry-over of mineral particles in the bubbles.

To achieve the high heat transfer, GE designers fluted the outside wall of the evaporator. While steam can condense in the troughs, the crests are film free because of the effect of a pressure gradient produced by surface tension. As a result, the average steam-side temperature is considerably higher than in other evaporator designs.



Pressure gradients, set up from crest to base, keep condensate film in the ridges. Liquid-free areas around the crests maintain high heat-transfer coefficients.



Why it will pay to design your high reduction gearing with Gleason HRH*

If you want to make your transmission more quiet or more compact or more flexible, take a good long look at the HRH set shown above.

This single set of gears gives a reduction of 66 to 1.

The action is quiet and smooth and continuous because the pinion teeth *wrap around* the gear teeth. With this design you can work such quiet operation into your designs even with a one- or two-tooth pinion member.

You can add the rigid support of a straddle mounting, since bearings can be put on both ends of the pinion.

HRH gear ratios are made with proven face mill cutting techniques, assuring complete control of tooth contact pattern to compensate for any assembly or operating condition.

HRH gear ratios are designed with the *full* assistance of all Gleason engineering services. We work with you on the practical design aspects and carry through to the development of prototypes. Then we furnish both machines and tooling for full production—*without royalties.*

Find out what HRH gearing can do for your transmissions. Send for our design form sheet and then send us the gear ratios and sizes you want. We'll send back detailed recommendations promptly.

*Trademark for Gleason High Reduction Hypoids

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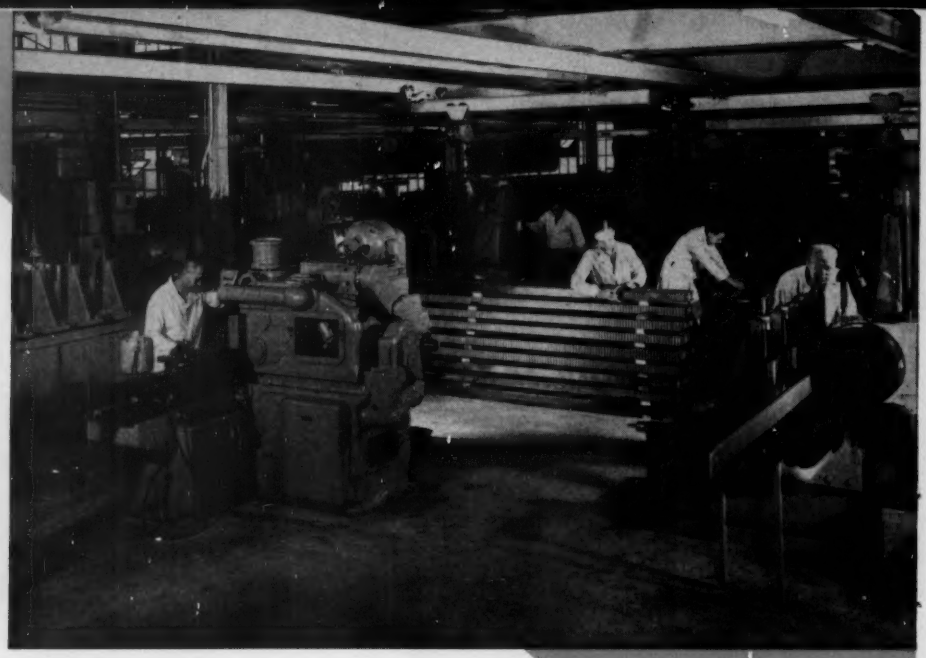
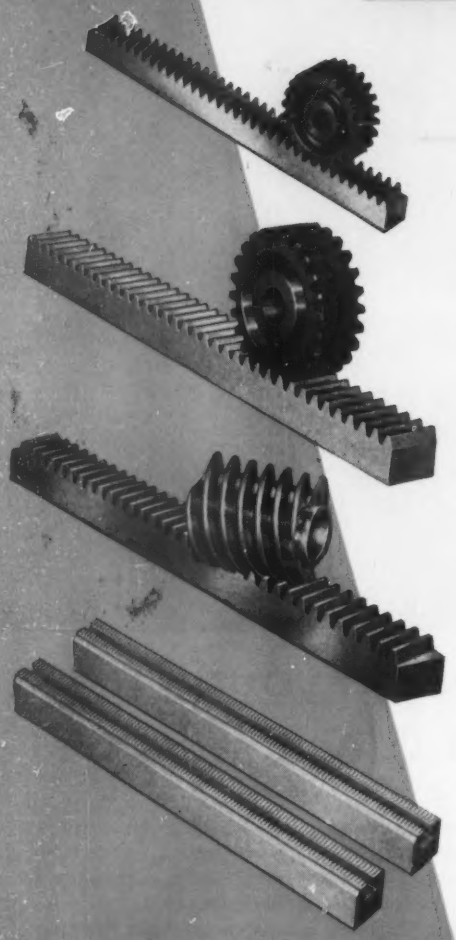
GEAR RACKS





...any type,
...any size,
...any material

with quality as a first consideration

Throughout industry, manufacturers depend on ILLINOIS GEAR to meet their exacting specifications for quality gear racks . . . from the large powerful, heavy pitch racks for steel mill equipment to the precision spur or helical racks for machine tools.

And there's good reason; these manufacturers expect *and get* the dependability and superiority proven by the performance of these racks throughout the world.

Whatever your requirements are for changing rotary power to linear power depend on ILLINOIS GEAR for racks that are made right with quality as the first consideration.

Look for this mark ILG® . . . the symbol on finer gears

ILLINOIS GEARS Reg U S Pat Off

Gears for Every Purpose ... one gear or 10,000 or more

ILLINOIS GEAR & MACHINE COMPANY

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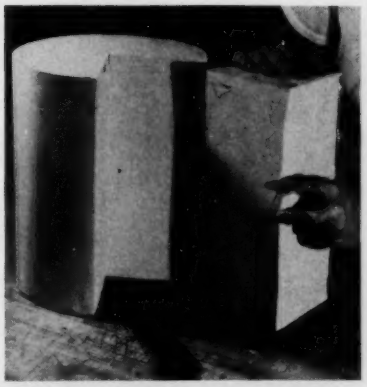
Circle 416 on Page 19

Unlimited Thickness Offered by New 24-Hour RTV Silicone

MIDLAND, MICH.—A silicone rubber that can be cured at room temperature in any thickness is announced by Dow Corning Corp. Silastic RTV 601 requires only a catalyst (no heat, pressure, or moisture) to set up in 24 hours' time. Since the vulcanization reaction produces no volatile by-products, venting is not necessary during cure.

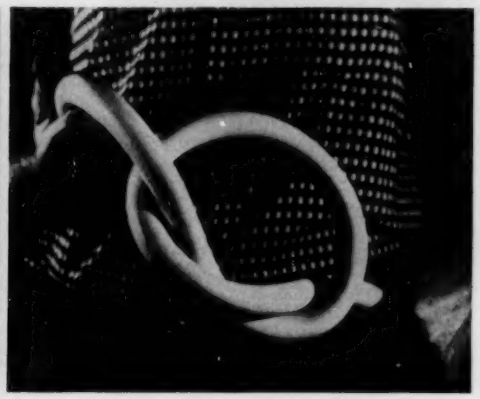
The material begins to vulcanize as soon as the catalyst is added, remaining workable for about an hour and a half. Working time can be extended by cooling, or catalyst can be added to speed set-up, both without significantly affecting properties. Immediately after vulcanizing, parts or sections made from Silastic RTV 601 can be used at temperatures from −100 to 500 F.

Applications of the new silicone rubber range from the making of flexible molds and casting of prototype parts, to potting and encapsulating deep or totally enclosed electrical and electronic components. Before curing, it is a low-viscosity fluid rubber and will flow into and around intricate designs.



Uniformly firm and resilient, a 60-lb mass of Silastic RTV 601 cured in less than 24 hours without heat, pressure, or moisture (right).

To demonstrate its unique ability to cure at room temperature even when totally confined, some of the material was poured into a glass tube which was then sealed at both ends. After 24 hours, a length of rubber was removed—fully vulcanized and firm and flexible from end to end.



EJC Updates Engineering Salary Data

NEW YORK — Engineering-salary levels rose slightly less than five per cent per year between 1958 and 1960, according to a survey conducted by the Engineering Manpower Commission, Engineers Joint Council. The median annual salary now stands at $9600.

Rate of increase is down from the period 1953-58, when it averaged almost 6.5 per cent per year. However, in 1953 the median salary was only $6500; while percentage increases have dropped, actual pay hikes appear to be about the same ($416 per year in '53 compared to $425 in '60). In the surveys for '56 and '58 increases averaged $500 per year.

Fourth in the series of EMC surveys, "Professional Income of Engineers—1960" uncovers many interesting statistics:

- Engineers are a young group; median age is about 32 and graduation age was 22.
- Salary increases build up quickest during early years, slowing down after about 20 years experience (recently this tendency has been less pronounced).
- There is still a marked difference between engineering salaries in industry, government, and education. Of particular note is the 14.3 per cent increase in income of engineering teachers between '58 and '60.

The survey (available from EMC) contains data on engineers' salaries in 22 subdivisions of industry, including separate curves for Ph.D., Sc.D., and M.S. graduates. Also included are federal, state, and local-government engineers, college teachers, technical-institute teachers, and engineering-society officers. The report covers more than 190,000 engineers—about one quarter of the entire U. S. engineering force.

Engineering Salaries Since 1953

Year	Median Salary (dollars)	Annual Increase (per cent)	Annual Increase (dollars)
1953	6500	6.4	416
1956	7750	6.5	500
1958	8750	5.7	500
1960	9600	4.4	425

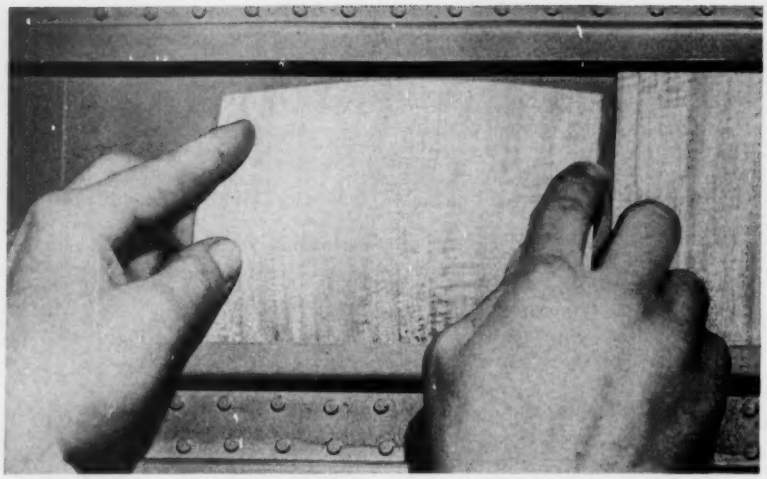
Median Engineering Salaries, 1960

Experience (years)	All Engineers	Employment: Industry	Employment: Government	Employment: Education
1	6725	6775	6275	5375
5	8100	8200	7175	7350
10	9875	9975	8750	9100
15	11,000	11,250	9075	10,950
28	12,450	12,575	10,650	12,575

Vinyl-Foam Tape Stops Metal Shake

ST. PAUL, MINN.—By converting vibration to heat, a new foam tape developed by Minnesota Mining and Mfg. Co. dampens resonant vibration and noise in sheet-metal structures up to 0.125-in. thick. The tape resists moisture, meets all of FAA regulations covering flame-resistant aircraft materials, and has high thermal insulation properties because of its foam structure.

Called "Scotchfoam" No. Y-9052, the new damping tape consists of a foam layer sandwiched between a plastic backing and a high-tack adhesive. Damping occurs when the embossed-vinyl backing forces the specially compounded polyurethane foam to absorb vibrational energy. The adhesive keeps the foam in permanent contact with the vibrating surface of the sheet-metal object.



Foam, plastic, and high-tack adhesive make up this new vibration-damping tape. Designed for easy application, the tape has already found uses on jet, turbojet, and prop-driven aircraft and on helicopters. Vibrations originating from both air-borne and structure-borne energy are damped out.

Meetings and Shows

March 12-16—

American Society of Mechanical Engineers. Aviation Conference to be held at the Statler Hilton Hotel, Los Angeles. Additional information is available from ASME Meetings Dept., 29 W. 39th St., New York 18, N. Y.

March 13-17—

National Association of Corrosion Engineers. Annual Conference to be held at the Statler Hotel, Buffalo. Additional information can be obtained from NACE headquarters, 1016 M & M Bldg., Houston 2, Tex.

March 13-17—

Society of Automotive Engineers Inc. National Automobile and Production Meetings to be held at the Sheraton - Cadillac Hotel, Detroit. Further information can be obtained from SAE, 485 Lexington Ave., New York 17, N. Y.

March 16-17—

American Society of Mechanical Engineers. Textile Engineering Conference to be held at Clemson College, Clemson, S. C. Additional information can be obtained from ASME Meetings Dept., 29 W. 39th St., New York 18, N. Y.

March 20-23—

Institute of Radio Engineers. International Convention to be held at the Coliseum and the Waldorf-Astoria Hotel, New York. Additional information is available from IRE, 1 E. 79th St., New York 21, N. Y.

March 20-24—

American Society for Metals. Thirteenth Western Metal Exposition & Congress to be held at the Pan Pacific Auditorium, Los Angeles. Additional information can be obtained from ASM, Metals Park, Novelty, Ohio.

March 21-23—

American Power Conference to be held at the Sherman Hotel, Chicago. Sponsors are nine engineering societies, including American Society of Mechanical Engineers, National Association of Power Engineers, American Institute of Electrical Engineers, American Society of Civil Engineers, and American Society of Heating, Refrigeration, and Air Conditioning Engineers; Illinois Institute of Technology and 13 other universities. Additional information can be obtained from R. A. Budenholzer, Illinois Institute of Technology, 35 W. 33rd St., Chicago 16, Ill.

April 4-6—

National Microfilm Association. Tenth Annual Meeting and Convention to be held at the Sherman Hotel, Chicago. Additional information can be obtained from the association's executive secretary, Vernon D. Tate, P. O. Box 386, Annapolis, Md.

April 4-7—

Society of Automotive Engineers Inc. National Aeronautic Meeting, including production forum and display, to be held at the Hotel Commodore, New York. Further information is available from SAE headquarters, 485 Lexington Ave., New York 17, N. Y.

April 5-7—

Institute of Environmental Sciences. Annual Technical Meeting and Equipment Exposition to be held at the Park Sheraton Hotel, Washington, D. C. Further information can be obtained from Henry F. Sander, executive secretary of IES, P. O. Box 191, Mt. Prospect, Ill.

(*Please turn to Page* 41)

Circle 417 on Page 19→

YOU ASKED FOR IT!

WESTERN GEAR

VARI-MASTER

THE VARIABLE SPEED DRIVE YOU DESIGNED

WESTERN GEAR

Integral Type VARI-MASTER® *Variable Speed Drive*

for: 1 GREATER FLEXIBILITY 2 LATEST DESIGN IMPROVEMENTS

3 COMPACTNESS 4 INFINITELY ADJUSTABLE SPEEDS

5 MATCHLESS VERSATILITY 6 EASY MOTOR REPLACEMENT

The Vari-Master is a quality product with precision ground pulleys supported between bearings on an extra large diameter shaft. Both key and shaft are hard chrome plated and precision ground for extended pulley life with minimized fret corrosion and wear. The motor has its own cooling system independent of the cooling system of the Vari-Master transmission case. This allows for extended belt life and increased load factor. Pulleys are positive aligned to give automatic belt alignment. Tension spring for automatic correct belt tension and take up ▪ **Controlled speed for maximum production, increased machine efficiency ▪ Fast or slow speeds for varying load conditions ▪ Uniform rate of travel for machine surfaces ▪ A Vari-Master to meet your requirements**

Typical applications are tension, rate of liquid flow, speed controlling, rate of time for baking, drying, etc., in experimental laboratories for the control of processing materials.

Compare These Exclusive Features: 1. Compactness—maximum power in minimum space. **2.** Cooling fan for longer belt life.* **3.** Standard NEMA C motor with standard shaft. **4.** Hard chrome-plated shafts eliminate disc sticking.

* * *

Custom Design for Special Applications

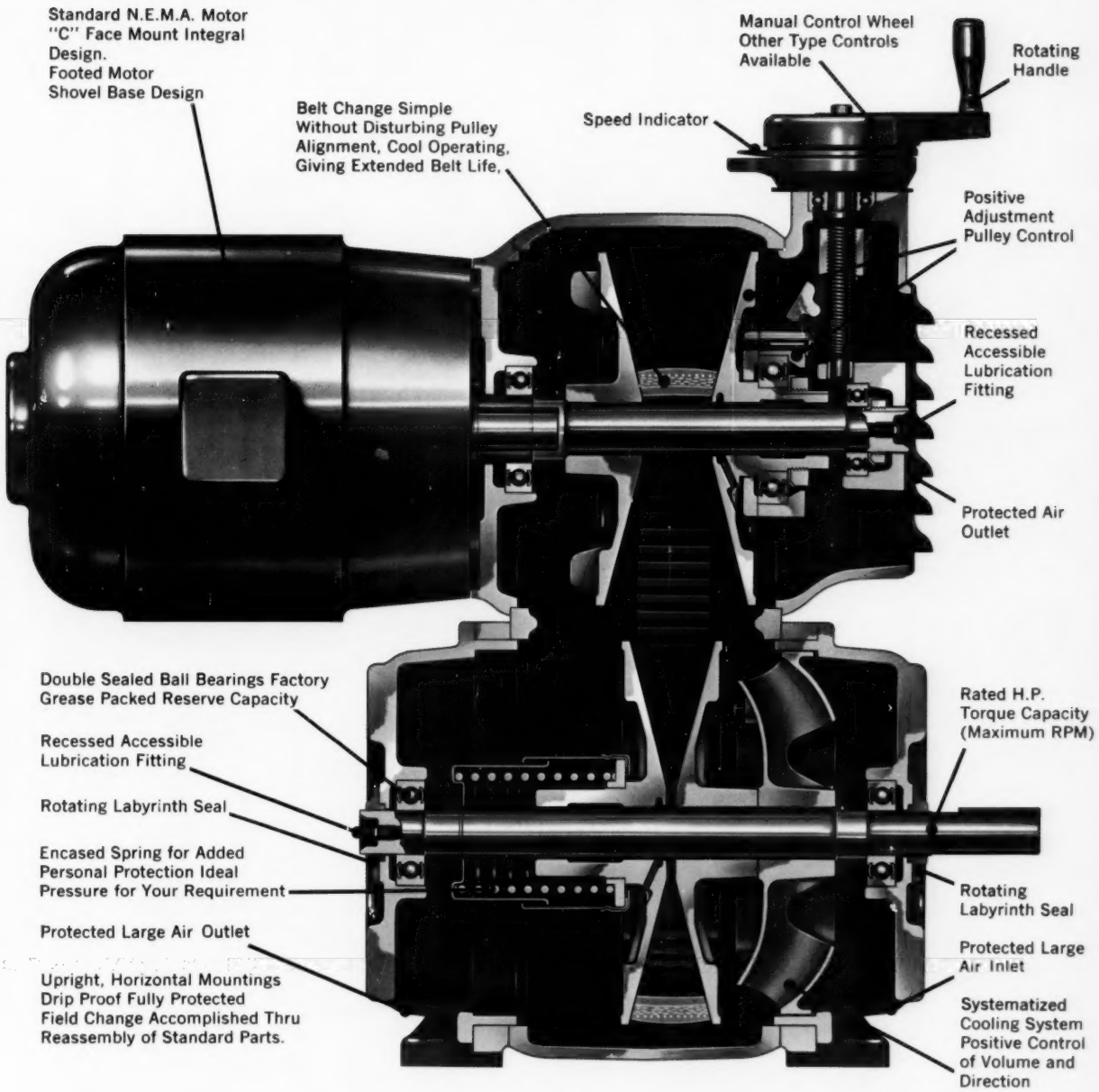
Sanitary design—the majority of requirements are met with standard design; custom changes are available to meet specifics.

Corrosion resistant—with minor changes, Vari-Master can be converted to meet the unusual conditions for this type of application. Submit operating conditions.

Shaft high inverted design—for direct connected loads (non gear units). Submit your requirements or request dimensions.

Various type flanges—standard type flanges listed in catalog. Modifications or other types available. Submit details. Special design applications invited. Have Western Gear submit a solution to your variable speed problem with a custom-built Vari-Master.

* PATENT PENDING


Standard N.E.M.A. Motor
"C" Face Mount Integral
Design.
Footed Motor
Shovel Base Design
Belt Change Simple
Without Disturbing Pulley
Alignment, Cool Operating,
Giving Extended Belt Life.
Manual Control Wheel
Other Type Controls
Available
Rotating
Handle
Speed Indicator
Positive
Adjustment
Pulley Control
Recessed
Accessible
Lubrication
Fitting
Protected Air
Outlet
Double Sealed Ball Bearings Factory
Grease Packed Reserve Capacity
Recessed Accessible
Lubrication Fitting
Rotating Labyrinth Seal
Encased Spring for Added
Personal Protection Ideal
Pressure for Your Requirement
Protected Large Air Outlet
Upright, Horizontal Mountings
Drip Proof Fully Protected
Field Change Accomplished Thru
Reassembly of Standard Parts.
Rated H.P.
Torque Capacity
(Maximum RPM)
Rotating
Labyrinth Seal
Protected Large
Air Inlet
Systematized
Cooling System
Positive Control
of Volume and
Direction

VARI-MASTER®
TYPICAL ASSEMBLIES

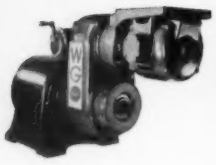
More than a quarter of a century of experience is designed into the Vari-Master with the features our customers want.

GREATER RELIABILITY—Precise machining and finishing techniques and careful heat treatment to uniform hardness are backed by Western Gear's uncompromising quality control methods. This means long life and quieter operation for the user. In addition, all units are full-load factory tested to insure complete reliability of performance.

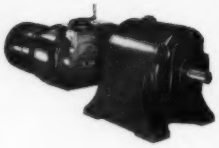
EASIER MAINTENANCE—The Vari-Master variable speed drives have been designed for easy maintenance in the field. Housings are completely accessible from either end and sides, for ease of inspection and routine maintenance. Disassembly and reassembly is fast and simple, requiring no special tools.

FLEXIBLE INVENTORY—Western Gear has designed its line of Vari-Masters utilizing the "building block" principle. This results in a minimum renewal parts inventory because of parts standardization and a high degree of interchangeability.

Vari-Master gearmotors, both integral and shovel base types, are offered in a wide variety of sizes and reductions.

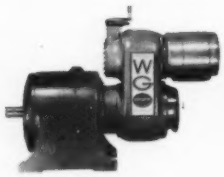


Shovel Base Vari-Master • Upright Design • Double Reduction

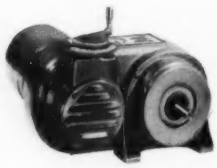


Integral Horizontal Vari-Master Double Reduction

Shovel Base Upright Vari-Master Low Output Shaft • (No Gears)



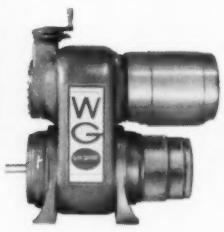
Integral Upright Vari-Master Double Reduction



Integral Horizontal Vari-Master (No Gears)

Integral Upright Vari-Master Low Output Shaft • (No Gears)

Integral Vari-Master • Vertical Flange Mount • Double Reduction



Integral Upright Vari-Master Magnetic Disc Brake

Integral Upright Vari-Master Right Angle Gear Head

VARI-MASTER®
CONTROLS

Easy access to control of the Vari-Master is assured regardless of the operator's working position. When the operator is working away from the control handle, or when the drive location is inaccessible, simple use of a mechanical or pneumatic control, or electrical accessories, assures complete and convenient control.

RAPID INTERCHANGEABILITY—Western Gear integral and shovel base type Vari-Master gearmotors and gearmotors are companion products which may be converted by simply interchanging packages in the field without disconnecting the gearmotor from its foundation or the driver shaft. Ease of changing ratio is another feature. This rapid interchangeability is important when unforeseen requirements for different output speeds or packages may arise.

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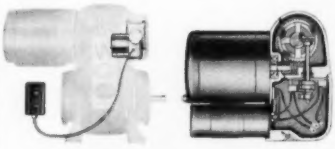
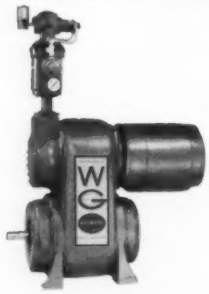


HEAVY DUTY REMOTE CONTROL MOTOR

RIGHT ANGLE DRIVE

DIRECT EXTENSION



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REMOTE SPEED INDICATOR

WG INDUSTRIAL PRODUCTS DIVISION

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(Continued from Page 36)

April 6-7—

American Society of Mechanical Engineers-Society for the Advancement of Management. Management Engineering Conference to be held at the Statler Hilton Hotel, New York. Further information can be obtained from ASME Meetings Dept., 29 W. 39th St., New York 18, N. Y.

April 9-13—

American Society of Mechanical Engineers. Oil and Gas Power Conference and Exhibit to be held at the Jung Hotel, New Orleans. Additional information is available from ASME Meetings Dept., 29 W. 39th St., New York 18, N. Y.

April 10-14—

International Institute of Welding. Annual Assembly, to be held at the Sheraton-Atlantic Hotel, New York, will join the American Welding Society meeting the following week. Additional information is available from AWS headquarters, 33 W. 39th St., New York 18, N. Y.

April 17-21—

American Welding Society. 42nd Annual Convention and Welding Exposition to be held at the Coliseum, New York. Technical meetings will be held at the Commodore Hotel. Additional information is available from society headquarters, 33 W. 39th St., New York 18, N. Y.

April 17-19—

Fifth Conference on Manufacturing Automation, cosponsored by Purdue University and Manufacturing Engineering Council and *Automation* magazine, to be held at Purdue University, Lafayette, Ind. Further information is available from K. E. Glancy, Div. of Adult Education, Purdue University, or *Automation,* Penton Bldg., Cleveland 13, Ohio.

April 17-21—

Business Equipment Exposition to be held in the Coliseum, New York. Sponsor is the Office Equipment Manufacturers Institute. Further information is available from OEMI, 777 14th St. N.W., Washington 5, D. C.

April 18-20—

New England Electrical Trade Show to be held in the Commonwealth Armory, Boston. Sponsor is the Electrical Manufacturers Representatives Club of New England. Additional information can be obtained from Charles A. Stone, 45 Morrissey Blvd., Boston 25, Mass.

April 20-21—

Society of the Plastics Industry Inc. Annual Western Section Conference to be held at the Hotel del Coronado, Coronado, Calif. Further information can be obtained from SPI headquarters, 250 Park Ave., New York 17, N. Y.

April 23-26—

American Society of Mechanical Engineers. Metals Engineering Conference to be held at the Penn Sheraton Hotel, Pittsburgh. Further information is available from ASME Meetings Dept., 29 W. 39th St., New York 18, N. Y.

April 24-26—

American Society of Mechanical Engineers. Annual Conference of the Metals Engineering Div. to be held at the Penn-Sheraton Hotel, Pittsburgh. Further information is available from ASME Meetings Dept., 29 W. 39th St., New York 18, N. Y.

May 9-11—

Western Joint Computer Conference to be held at the Ambassador Hotel, Los Angeles. Further information can be obtained from conference headquarters, 721 N. La Brea Ave., Los Angeles 38, Calif.

Short Courses and Symposia

March 20-31—

Industrial Packaging Short Course to be held at Purdue University. Additional information is available from Mark E. Ocker, Conference Co-ordinator, Div. of Adult Education, Memorial Center, Purdue University, Lafayette, Ind.

March 27-28—

Production Institute, sponsored by the American Society of Tool and Manufacturing Engineers, to be held at the University of Wichita. Theme is "New Frontiers in Pro-

SPHERCO®
BEARINGS

If you have applications involving linkage or transfer of motion, SPHERCO Bearings can supply your needs in a wide variety of materials with a quality that will give you top performance under normal or high temperature conditions.

WRITE FOR BULLETIN 560

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←Circle 417 on Page 19

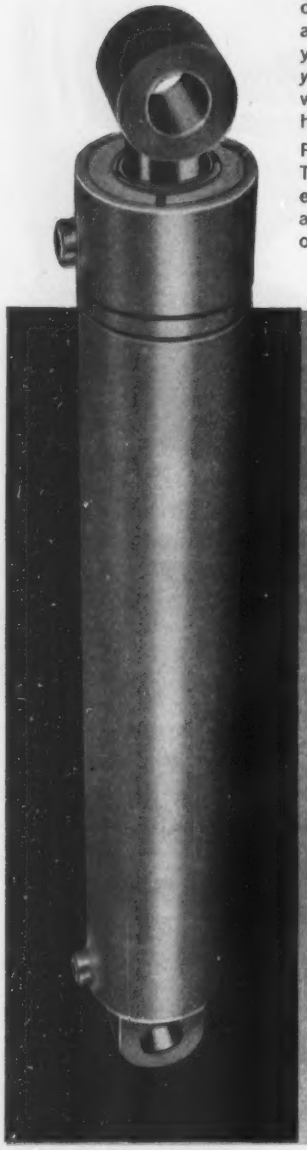
Circle 418 on Page 19

demand

THE VERY FINEST AND YOU GET IT FROM

B-H-E-W! If your job application demands precision hydraulic cylinders and you insist upon better on-the-job results, always *demand* B-H-E-W products! Only B-H-E-W offers designs and basic design techniques plus the added advantage of a complete staff of trained specialists to analyze your specific application. *You* benefit because *you* obtain B-H-E-W products at production prices which are precision-manufactured to produce the highest level of performance!

PRODUCTION PARTS SAVE YOU MONEY, DO THE JOB BETTER! B-H-E-W basic cylinders can easily be modified to fit your *specific* product applications. *You* benefit from production economies; you get custom-built cylinders!



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WRITE TODAY for free Hydraulic Cylinder Engineering Reference data. 78 dimensional basic designs for general purpose and special double- and single-acting cylinders. SAVE TIME!

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ducibility," and subjects include aluminum castings, metal bonding, research and development costs, numerical control, and brazing honeycomb sections. Further information can be obtained from Prof. B. M. Aldrich, Co-ordinator, University of Wichita, Wichita, Kans.

March 27-31—

Fourth Symposium on Temperature—its Measurement and Control in Science and Industry to be held at Veterans Memorial Hall and the Deshler-Hilton Hotel, Columbus, Ohio. Sponsors are Instrument Society of America, American Institute of Physics, and National Bureau of Standards. Further information is available from ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

March 28—

17th Annual Quality Control Clinic to be held at the University of Rochester, Rochester, N. Y. Sponsor is the Rochester Society for Quality Control. Further information can be obtained from Albert D. Rickmers, Associate Professor, College of Graphic Arts and Photography, School of Photography, Rochester Institute of Technology, 65 Plymouth Ave. South, Rochester 8, N. Y.

March 28-29—

Symposium on Nucleonics in Flight to be held at the Statler-Hilton Hotel, Dallas, Texas. Symposium will consider nuclear aspects of atmospheric and space systems for manned and/or unmanned space travel. Further information is available from Eldred L. Burkhard, Chairman, North Texas Section, American Nuclear Society, Convair Div., Fort Worth, Texas.

April 5-7—

Engineering Institute on Statistical Quality Control Appreciation to be held at the University of Wisconsin. Additional information can be obtained from Engineering Institutes, 3030 Stadium, University of Wisconsin Extension, Madison 6, Wis.

April 11-12—

Seminar on Engineering Standards: Procedures, Practices, and

Circle 419 on Page 19

Problems to be held at the University of Wisconsin. Further information is available from Engineering Institutes, 3030 Stadium, University of Wisconsin Extension, Madison 6, Wis.

April 17-19—

Seventh National Symposium on Instrumental Methods of Analysis, to be held at the Shamrock-Hilton Hotel, Houston. Sponsor is the Instrument Society of America; additional information is available from Meetings Services Dept., ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

April 17-21—

Short Course on Strain Gage Techniques, sponsored by the Society of Experimental Stress Analysis and Southwest Research Institute, to be held at the Granada Hotel, San Antonio, Texas. Emphasis will be placed on high and low-temperature applications, and lectures will be supplemented by laboratory work. Additional information can be obtained from Dr. M. M. Lemcoe, Southwest Research Institute, P. O. Box 2296, San Antonio 6, Texas.

April 18-19—

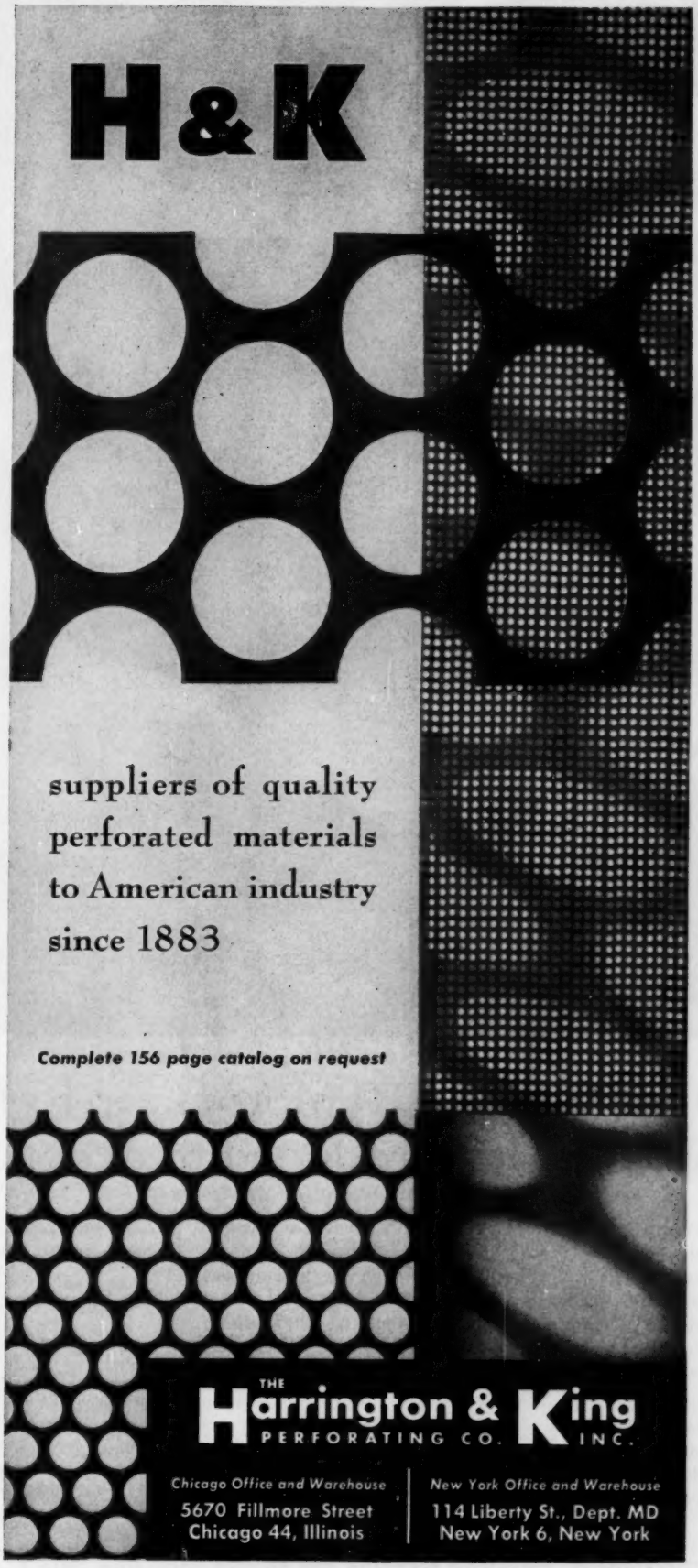
Process Planning-Operations Research Seminar to be held at the Statler Hilton Hotel, Cleveland, under the sponsorship of the American Society of Tool and Manufacturing Engineers. Further information is available from ASTME headquarters, 10700 Puritan Ave., Detroit 38, Mich.

April 30-May 4—

Aero-Space Instrumentation Symposium, sponsored by Instrument Society of America, to be held at the Adolphus Hotel, Dallas. Further information is available from W. J. Gabriel, Group Engineer, Convair Div., General Dynamics Corp., Ft. Worth, Texas.

May 8-9—

Lubrication Symposium, sponsored by American Society of Mechanical Engineers, to be held at the Deauville, Miami Beach, Fla. Additional information is available from ASME Meetings Dept., 29 West 39th St., New York 18, N. Y.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Circle 420 on Page 19

One Lamb FHP motor...up to 100,000 carbon copies mass-produced to exacting specifications

From a prototype . . . hundreds OR thousands of motors with absolute uniformity. Each and every motor produced has the same, discriminating, "built-in" perfection that you can expect with Lamb® manufacturing. This precise mechanical and dimensional uniformity of motor as an integral component for your powered product is extremely important . . . and Lamb makes sure you get it!

If you have a special motor problem . . . here's what you can expect from Lamb! *Into the design* of a Lamb motor goes years of experience in powering components for aircraft, domestic and industrial products. *Out of the design* comes a personalized motor that's dependable, smooth and efficient.

Cost-wise you're way ahead, because Lamb Motors are mass-produced at the most favorable cost.

Write today for descriptive folder. Or ask to have a District Engineer call and set up a personalized "Motor Conference".

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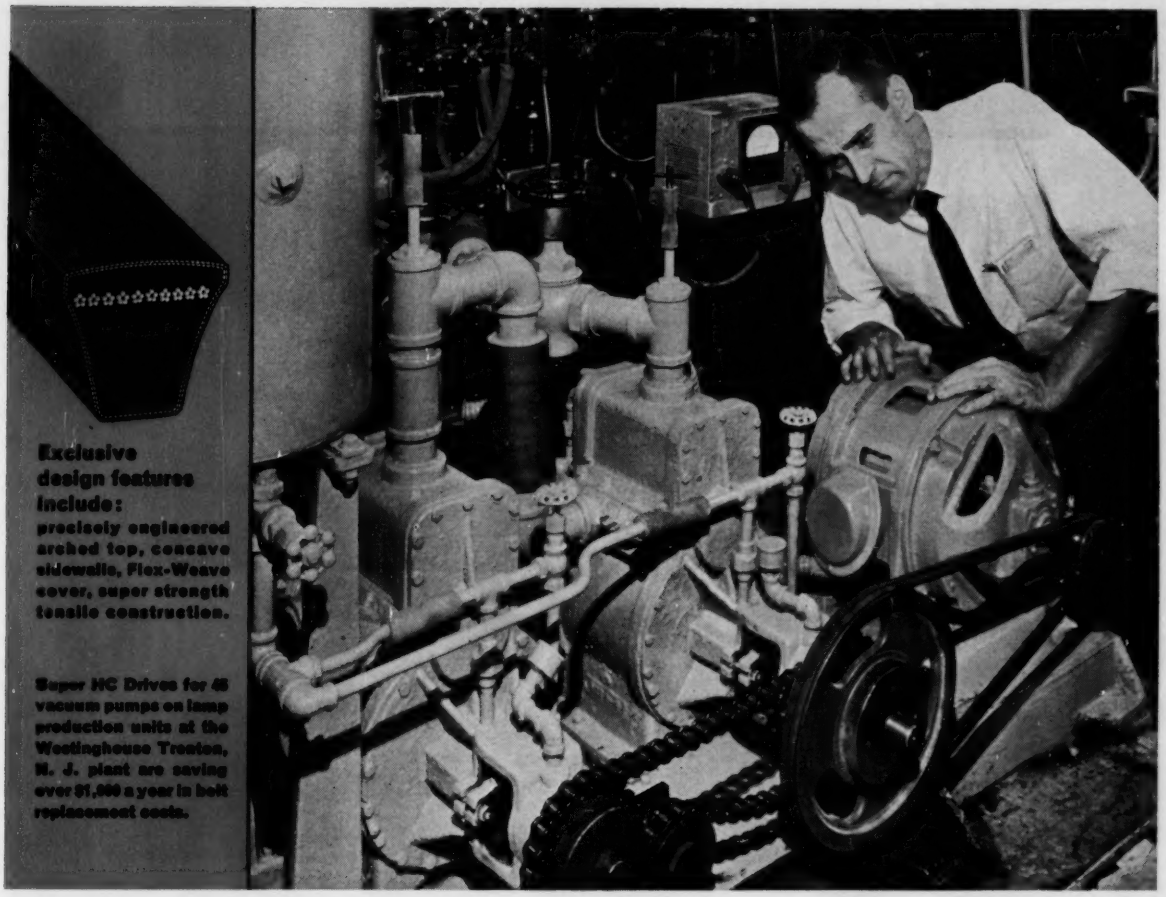

Exclusive design features include:
precisely engineered arched top, concave sidewalls, Flex-Weave cover, super strength tensile construction.

Super HC Drives for 45 vacuum pumps on lamp production units at the Westinghouse Trenton, N. J. plant are saving over $1,000 a year in belt replacement costs.

Westinghouse converts drives on 45 machines to new Gates Super HC High Capacity V-Belts

When drive space is limited, a driver sheave too small in diameter is sometimes used—though not recommended. Constant flexing over a small sheave is severe punishment for V-belts. Because of this, conventional V-belts lasted 4 months or less on the vacuum pumps on lamp production units at the Westinghouse Lamp Division plant in Trenton, N.J.

Now, with space-saving Gates Super HC High Capacity V-Belt Drives on all 45 machines, all belts are still running strong after more than 1½ years . . . a saving of over $1,000 in belt replacement costs plus even greater savings through reduced down-time.

The Gates Super High Capacity V-Belt is a new concept in V-belt design.

It is industry's first and most advanced high capacity V-belt. Because of exclusive design features, Gates Super High Capacity V-Belts transmit up to 3 times more horsepower than conventional V-belts in the same space. Or the same power can be handled with fewer belts and smaller sheaves in less space.

As a result, Gates Super HC Drives save up to 50% in drive space . . . cut your drive costs as much as 20% . . . reduce drive weight 20% and more . . . and make possible further savings in material costs.

Your local Gates Field Engineer is an experienced, fully-qualified drive design expert. Contact him for Super HC design information and for design help.

Building the future on 50 years of progress

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Gates Super HC V-Belt Drives

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the toughest wear problem known for

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• the hardest metal known •

***** If you've got a real wear problem, it's time you take a long, hard look at Carmet Cemented Carbides . . . and how they can extend operational life and reduce costs.

Carmet Cemented Carbides possess the perfect combination of extreme hardness, strength, and abrasion resistance for the battering that wear parts must take . . . the rubbing, scrubbing, sliding, and scraping.

Carmet Cemented Carbides have a compressive strength higher than any metal or alloy . . . cast, rolled, or forged. They are the hardest man-made metal . . . next to a diamond in hardness, yet far tougher . . . three times stiffer than steel, and up to 100 times more abrasion resistant.

And you can put this hardness and wear resistance where it will do the most good. Carmet wear parts can be made in practically any shape . . . adapted to any function.

For all the facts on carbide wear parts, get Carmet's new booklet on design for wear resistance. It's packed with charts, graphs, case histories, and special design criteria for top wear parts performance. Ask your local A-L representative for a copy, or write: *Allegheny Ludlum Steel Corporation, Carmet Division, Oliver Building, Pittsburgh 22, Pennsylvania. Address Dept. MD-12.*

1095

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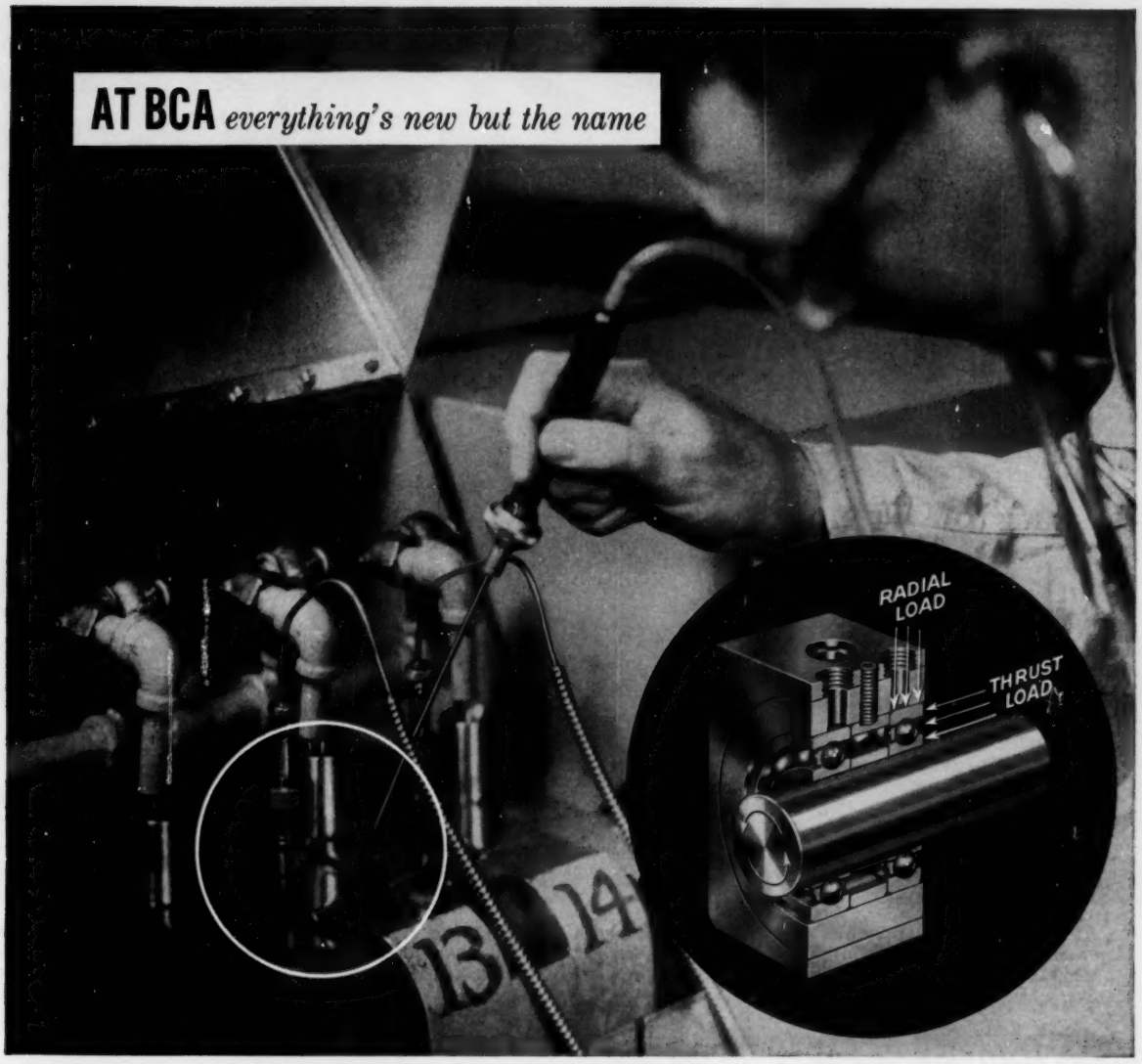

BALL BEARING "HEARTBEATS"

checked with unique new fatigue tester

With a stethoscope checking the "heartbeats," this unique fatigue tester is putting BCA ball bearings through a battery of exaggerated, but controlled, speed and load tests.

The fatigue testing machines are part of a group of testing devices that provide essential data for BCA's research program. Hydraulically testing BCA bearings at a variety of rotational speeds and under many combinations of radial and thrust loads, each machine checks to see that BCA ball bearings are maintaining the highest fatigue life standards . . . evaluates the fatigue characteristics of new ball bearing materials and new processing methods . . . helps select ball bearing lubricants to provide the longest possible fatigue life.

These machines and BCA's other unusual testing devices are designed and built to help us develop the highest quality ball bearings available. By simulating actual operating conditions, BCA ball bearings can be tested to *exceed* customer specifications.

BCA ball bearings are standard equipment throughout industry—for both original and replacement applications. BCA's complete line of ball bearing types and sizes . . . design, engineering and manufacturing skill . . . plus research and testing facilities, are some of the reasons that automotive, machine tool, earth moving, agricultural equipment manufacturers specify BCA. We'd like to serve you—with high-performance bearings or technical assistance. Contact Bearings Company of America, Division of Federal-Mogul-Bower Bearings, Inc., Lancaster, Pa.

BCA

BEARINGS COMPANY OF AMERICA

ball bearings

DIVISION OF FEDERAL-MOGUL-BOWER BEARINGS, INC.

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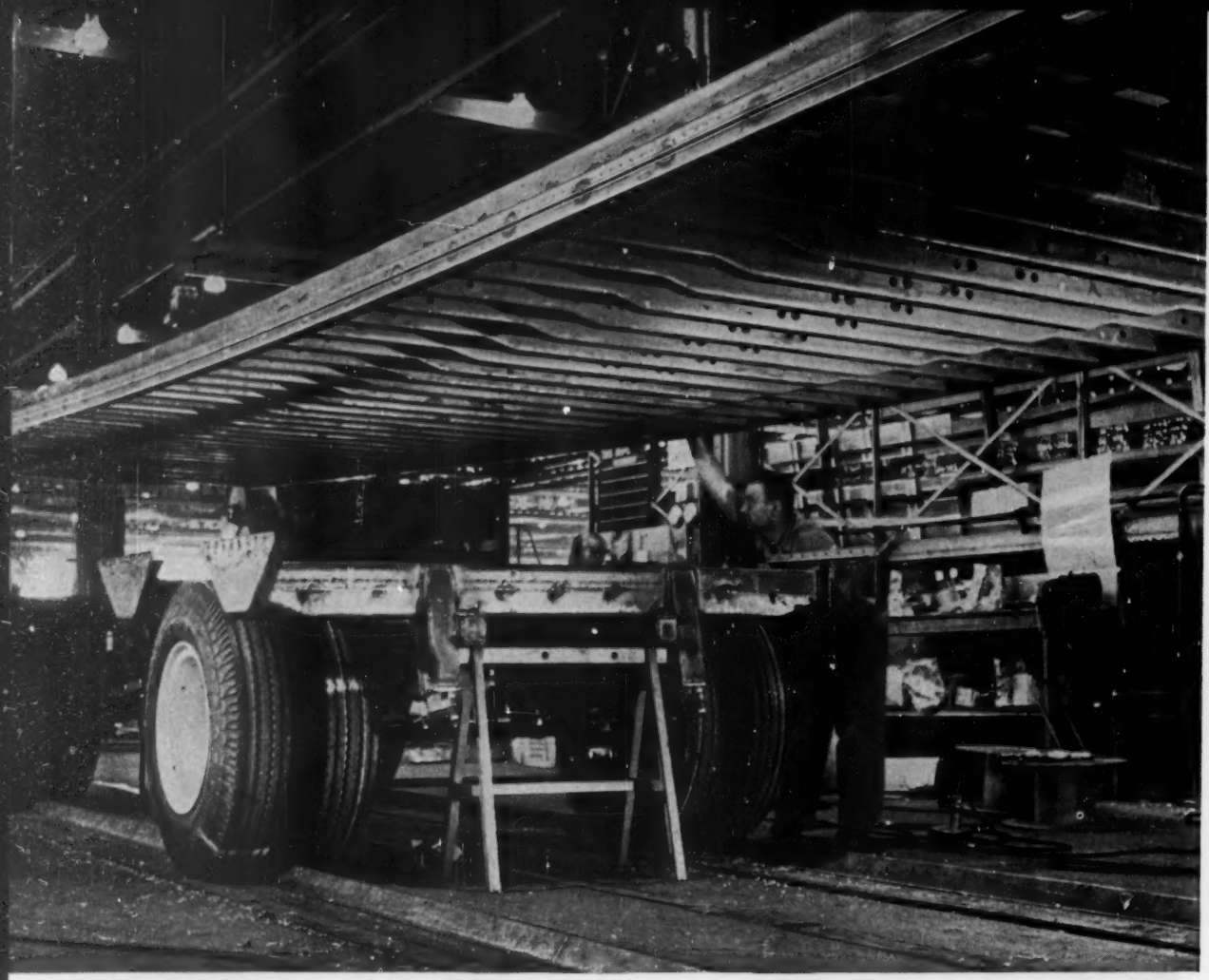


At Fruehauf Trailers' huge Avon Lake, Ohio, plant, crossmembers made from PITT-TEN high strength structural sheet provide 22 percent more payload.

Here, on the assembly line, a Fruehauf trailer bed made with Pittsburgh Steel Co. PITT-TEN is swung onto the underconstruction assembly.

As Trailer Bed Crossmembers

Fruehauf Gets 22% More Payload With Pittsburgh Steel's New PITT-TEN

Twenty-two percent more payload—that's what Fruehauf is building into the framework of giant trailers assembled with crossmembers made of PITT-TEN, Pittsburgh Steel Company's new high strength structural sheet.

Fruehauf uses PITT-TEN #1 at its Avon Lake, Ohio, plant—the largest trailer manufacturing facility in the world—because it offers a combination of benefits that . . .

- **Cuts deadweight with no loss of strength**
- **Lengthens service life through superior corrosion resistance**

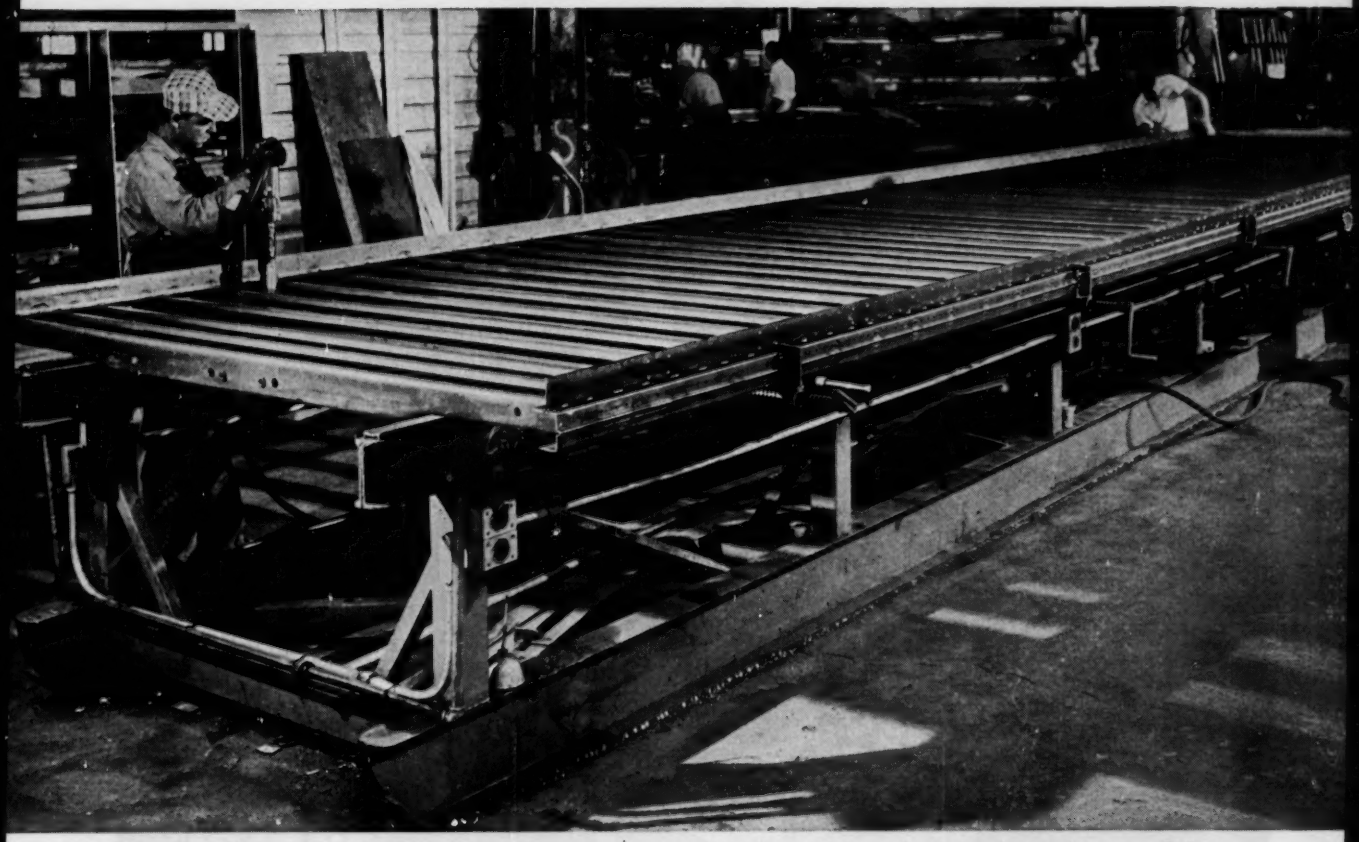
- **Light Yet Strong** — Fruehauf tries to make its trailers as light as possible with no sacrifice in strength. Trailer bed crossmembers made of high strength PITT-TEN are lighter, for equal strength, than mild steel.

The weight saving amounts to more than eight pounds for each piece. That's because three pounds of PITT-TEN do the work of nearly four pounds of ordinary sheet steel. At the same time, it provides all the strength needed for years of hard use.

Corrosion resistance is another problem in trailer operation. Fruehauf trailers are used under all types of conditions that could create maintenance headaches if the proper material were not used.

PITT-TEN #1 has four to six times the resistance of carbon steel to atmospheric corrosion. So, Fruehauf specifies PITT-TEN to reduce maintenance costs.

The trailer part basically is a channel 93⅞ inches long, 2 inches deep and 3 inches wide. Its width is expanded to 4½ inches on one side by an offset that extends most of its length. In addition, a ¾-inch



During assembly of Fruehauf trailer bed, cross-members made from high strength structural PITT-TEN are riveted to the side rail. PITT-TEN #1 reduces maintenance requirements of Fruehauf trailers through superior corrosion resistance. It has four to six times the corrosion resistance of carbon steel to atmospheric corrosion. PITT-TEN also cuts deadweight with no loss in strength.

return flange is applied full length to both edges.

Fruehauf engineers point out that forming this piece with offset and flange in high tensile steel would be a tricky business without consistent quality — and with PITT-TEN Fruehauf has a steel that does the job.

PITTSBURGH STEEL NEW SOURCE – This is one of several applications which mark the entry of Pittsburgh Steel in the high strength steel market, one of the fastest growing in metalworking.

That means this:

Fabricators of high strength steel structurals—or any product where the weight/strength ratio is a factor—now have a new source of supply.

In the eight years Pittsburgh Steel has been producing flat-rolled products, it has become recognized for the unexcelled quality of its steel sheet and strip. Now PITT-TEN is being produced by the same fine steelmaking and steel rolling facilities which have earned that reputation for quality.

PITT-TEN is produced in three grades, each with specific physical properties. Briefly, here they are:

PITT-TEN #1—An all-around high strength structural sheet that offers a combination of benefits. First is greater strength without increased weight; or equal strength with a lighter section. Second is longer product life, less maintenance through greater resistance to corrosion (four to six times that of mild carbon steel.)

PITT-TEN #2—high strength sheet with exceptional formability. This grade is produced to tensile and yield requirements to meet forming problems of specific fabricated parts.

PITT-TEN "X"—produced to guaranteed minimum yield points of 45,000 and 50,000 psi. This grade is especially useful where the controlling factor is a reduction in weight without loss of strength.

If your product's success depends on weight/strength factors, then Pittsburgh Steel's new PITT-TEN can benefit you, too.

Let one of our service metallurgists show you how. They're as familiar with steel fabricating problems as they are with steelmaking problems. Just contact one of the sales offices listed here.

Pittsburgh Steel Company

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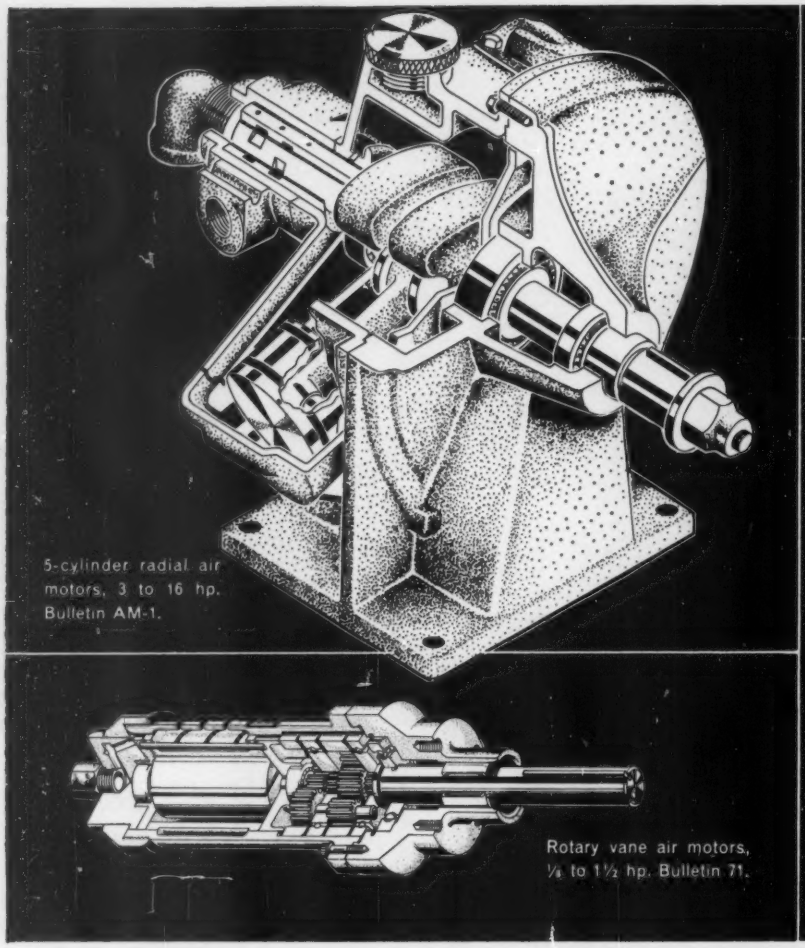
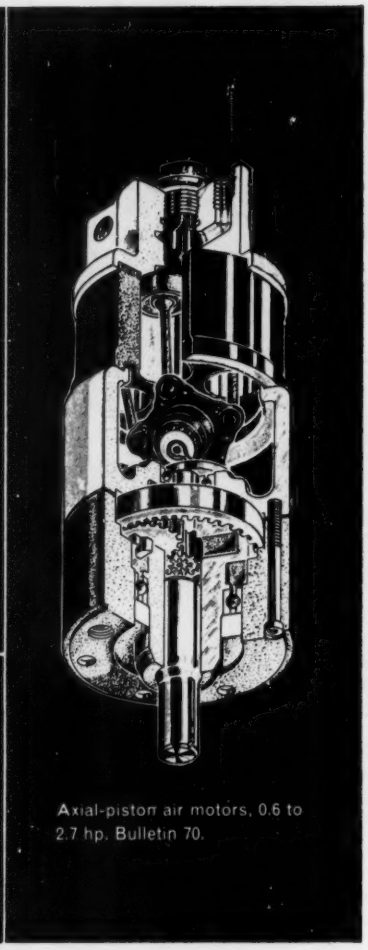
Circle 425 on Page 19

When you analyze power values, look to air power for new ideas



5-cylinder radial air motors, 3 to 16 hp. Bulletin AM-1.

Rotary vane air motors, ⅛ to 1½ hp. Bulletin 71.



Axial-piston air motors, 0.6 to 2.7 hp. Bulletin 70.

MEET ALL THESE POWER NEEDS

- High starting torque
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- Cool operation
- Instantaneous starts and stops
- Consistent torque output
- Spark-resistant characteristics
- Thrust or axial spindle loads
- Enclosed construction
- Output from ⅛ to 16 hp

Your Gardner-Denver specialist will be glad to consult with you in putting air power to work in your new designs.

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Flexonics Hi-Flex is a new, *all-new* corrosion-resistant, helically-formed metal hose. It is new in design, new in method of tube forming, new in manufacture . . . and it is subjected to the most rigid quality control. Hi-Flex hose is your answer for cryogenic applications, where cleanability, high pressures, and wide temperature ranges are critical . . . for hydraulics and pneumatics, where pressures and flexibility are design criteria . . . and for many other demanding aeronautical, missile, and industrial applications.

Hi-Flex hose is available for low, medium, and high pressures, in sizes from ¼" through 1¼". Mail coupon for copy of new Catalog 200E.

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REX-WELD—corrugated hose for high pressures and temperatures. Sizes from ¾" to 24".
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Flexonics

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In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

METAL and SYNTHETIC HOSE
EXPANSION JOINTS
BELLOWS • SPECIAL TUBULAR ASSEMBLIES

SUBSIDIARY OF CALUMET & HECLA, INC.

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ATTACH TO YOUR LETTERHEAD

Flexonics Corporation
350 E. Devon Avenue
Bartlett, Illinois

Gentlemen:
Please send me a copy of your new Catalog 200E, on Flexonics Hi-Flex Metal Hose.

OIL SEALS
in Design
Engineering

Garlock KLOZURE* Oil Seals stop oil leakage at bearings, increase efficiency of Denison Variable-Volume Hydraulic Pumps.

Denison designs hydraulic pumps around Garlock KLOZURE Oil Seals to assure maximum sealing efficiency.

Where pressures are too high for ordinary lip seals, KLOZURE Oil Seals prevent leakage of hydraulic oil and protect vital bearings as temperatures reach 150°F, pressures rise to 35 p.s.i., and shafts whirl at 1800 r.p.m. In use for the last twelve years, the seals have given complete satisfaction on the well-known line of axial piston and vane-type pumps made by Denison Engineering Division of American Brake Shoe Company.

Wherever bearings must have the best protection, Garlock KLOZURE Oil Seals are specified. On pumps like Denison . . . in steel mills . . . on power shovels and lift trucks . . . for motors, KLOZURE Oil Seals prevent leakage of lubrication, seal out harmful foreign matter. Whatever the application, there is KLOZURE Oil Seal to do the job. They are oil and grease resistant, impervious to mild acids and alkalies, non-abrasive, and will withstand temperatures from −40°F to +250°F. For extreme conditions, Garlock furnishes sealing elements resistant to practically any fluid, and serviceable as high as +500°F.

Availability is another prime reason for selecting Garlock KLOZURE Oil Seals. Once your design is finalized, you may select the proper seal from over 1800 stock models available from 180 national bearing distributors, including one near you.

It makes good sense to design with KLOZURE Oil Seals, as Denison and hundreds of other leading companies have found. See how you can benefit—call in your local Garlock representative. You will find him at the nearest of the 26 Garlock sales offices and warehouses throughout the U.S. and Canada. Or, write for Catalog AD-181. Garlock Inc., Palmyra, N. Y.

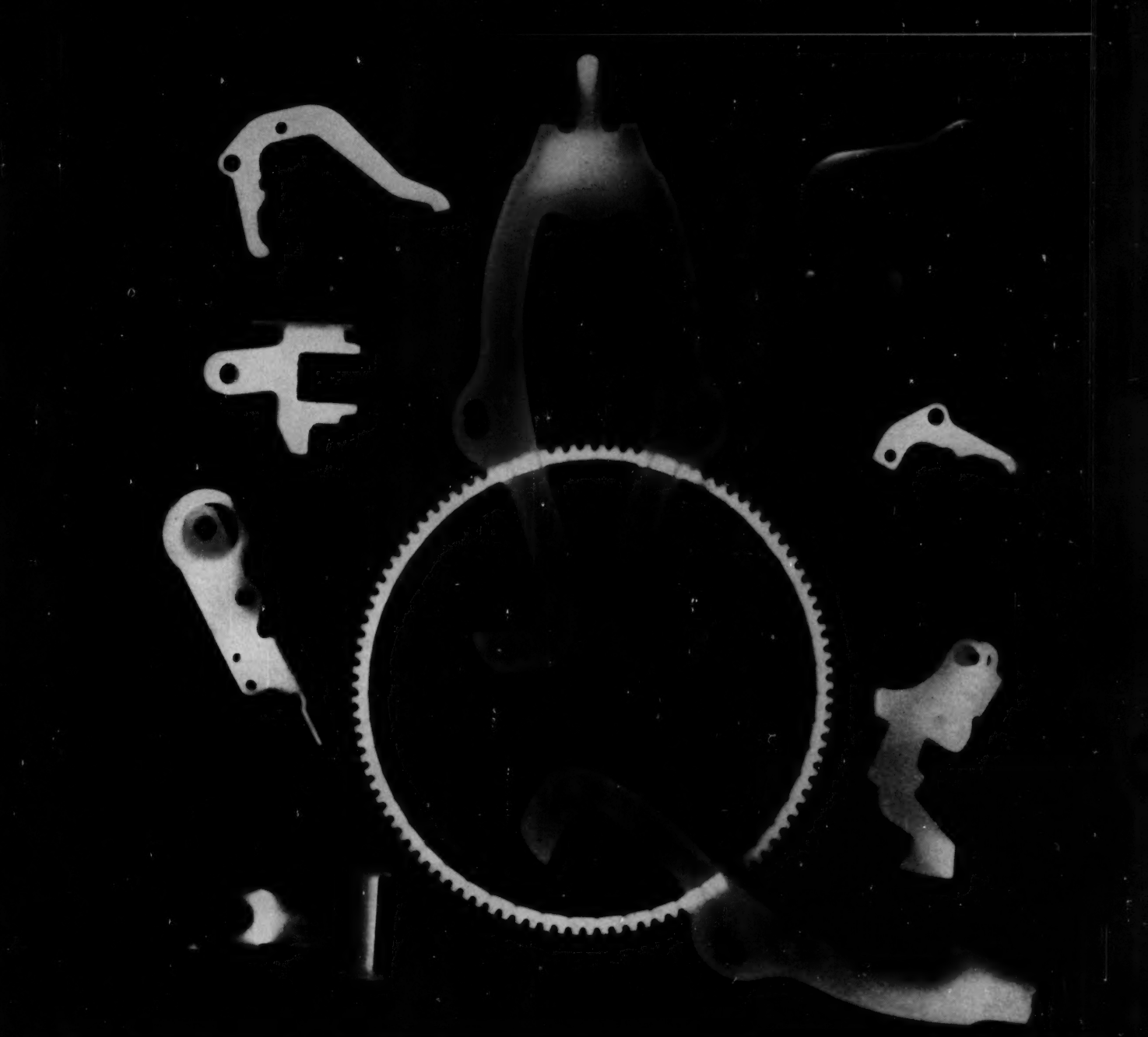
GARLOCK

Canadian Div.: Garlock of Canada Ltd.

Plastics Div.: United States Gasket Company.

Order from the Garlock 2,000 . . . two thousand different styles of Packings, Gaskets, Seals, Molded and Extruded Rubber, Plastics Products.

*Registered Trademark



WHICH OF THESE STAMPINGS COSTS LESS WITH PRECISION STEEL?

All of them, as a matter of fact. The design requirements of the finished parts may—or may not—call for closer than standard tolerances. But in an intricate, high-speed operation, a variation of 0.003" could result in costly production problems—frequent delays, constant tool adjustment, a high percentage of rejects, etc.

With J&L strip steel cold rolled to precision tolerances, you can expect uniform, trouble-free stamping. The reduced production costs plus the increased product reliability will more than offset the slightly higher initial cost of precision steel.

The key to J&L's superiority in strip steel processing is its ability to produce to standards more exact and precise than those in general use.

J&L's combination of specialized equipment and techniques, plus *experience*, are available to solve your stamping problems. For information, call your J&L Stainless and Strip Division representative or write to Dept. 1359.

Steel

J&L STRIP

LOW CARBON • HIGH CARBON • ALLOY • STAINLESS
TEMPERED SPRING STEEL • ZINC AND COPPER COATED

Jones & Laughlin Steel Corporation • STAINLESS and STRIP DIVISION • Youngstown 1, Ohio

Circle 429 on Page 19

SIMPLE AS A·B·C
A. Operator inserts microfilm aperture card.
B. Next, inserts sheet of ordinary paper, vellum, or offset paper master. Insertion starts automatic printing and processing cycle.
C. First print is automatically delivered in 30 seconds; subsequent prints (of the same or different drawings) every 15 seconds.

From microfilm to an 18″x24″ print ...in seconds and on ordinary paper!

You can have a dry, positive, 18″x24″ engineering print in seconds and on ordinary paper with the new XeroX® Copyflo® 1824 printer.

This remarkable machine, which requires no exposure settings or other adjustments, reproduces from a microfilm aperture card, making 18″x24″ prints—or smaller—at extremely low cost. It also copies onto vellum or offset paper masters.

Operation is automatic. Prints ready for immediate use emerge as fast as four a minute.

The quality of reproduction is superb. Images are sharp black-on-white and won't rub off. There is no odor, no waste, and the finished print may be written on with pen or pencil.

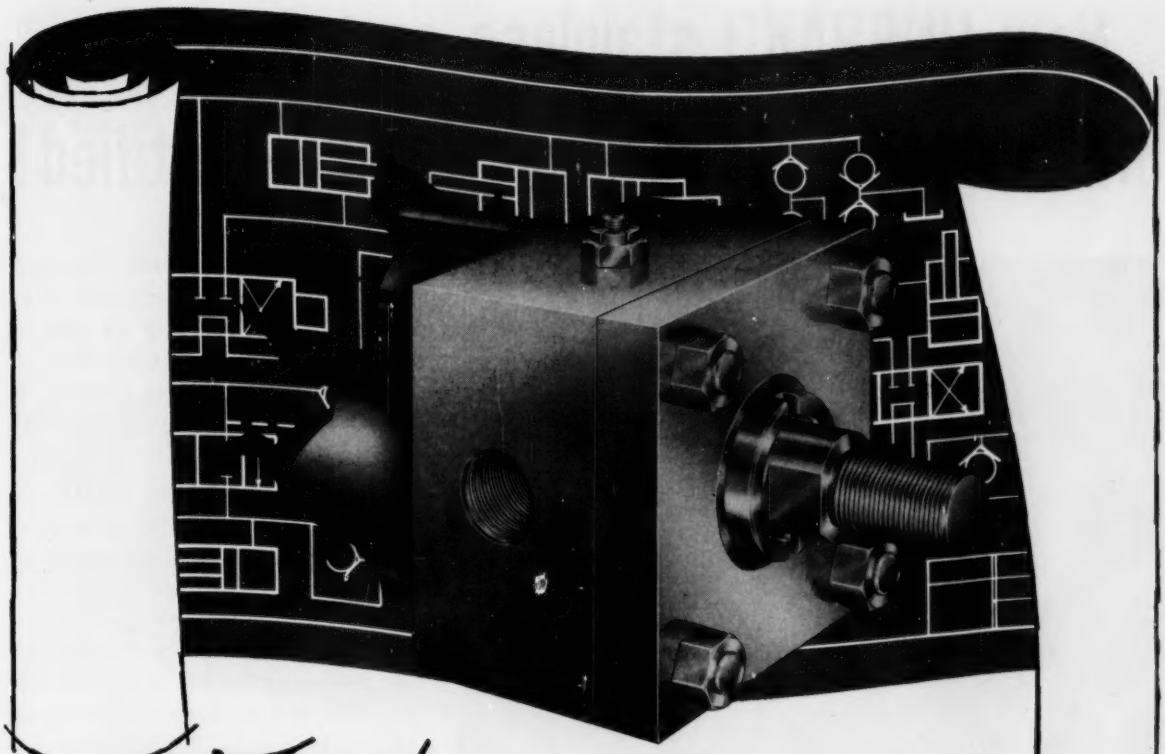
Regardless of your engineering-drawing-reproduction needs, you can now enjoy the tremendous savings in time, money, space, and materials of your own unitized microfilm system.

Formerly, such economies required a substantial reproduction need. Today, however, the Copyflo 1824 printer offers the same proportionate benefit to small-volume users as to large. No need now for vast files of engineering drawings. Microfilm aperture cards require only a fraction of the storage space required for other reproducibles. No more costly waiting for prints, which—made by a Copyflo 1824 printer—are so inexpensive your engineers can discard them after use.

Write today for our free 1824 booklet giving the full benefits you can expect from a Copyflo 1824 printer. HALOID XEROX INC., 61-169X Haloid St., Rochester 3, N.Y. Branch offices in principal U.S. and Canadian cities. Overseas: Rank-Xerox Ltd., London.

HALOID XEROX®

Circle 430 on Page 19

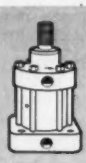


For the BLUEPRINT of your products...

SPECIFY T-J CYLINDERS . . . FOR YOUR POWER DRIVE DESIGN • APPLICATION OR REPLACEMENT MAINTENANCE

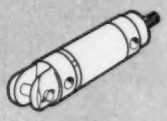
From its blueprint stage to its maintenance engineering requirement sheet, your product will assure MORE power drive precision and service, if T-J cylinders are specified. T-J's complete line too, from the Spacemaker to the new replaceable Squair Head, can be the answer to any power problem. Write or call The Tomkins-Johnson Company, 2425 W. Michigan Ave., Jackson, Michigan, today!

T-J OFFERS THE ONLY COMPLETE CYLINDER LINE

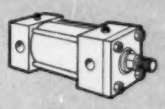


STANDARD HYDRAULIC

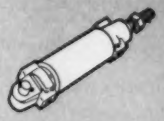
STANDARD PNEUMATIC



AIR and HYDRAULIC SPACEMAKER



AIR and HYDRAULIC SQUAIR HEAD



HIGH PRESSURE SPACEMAKER

PLUS complete catalog service

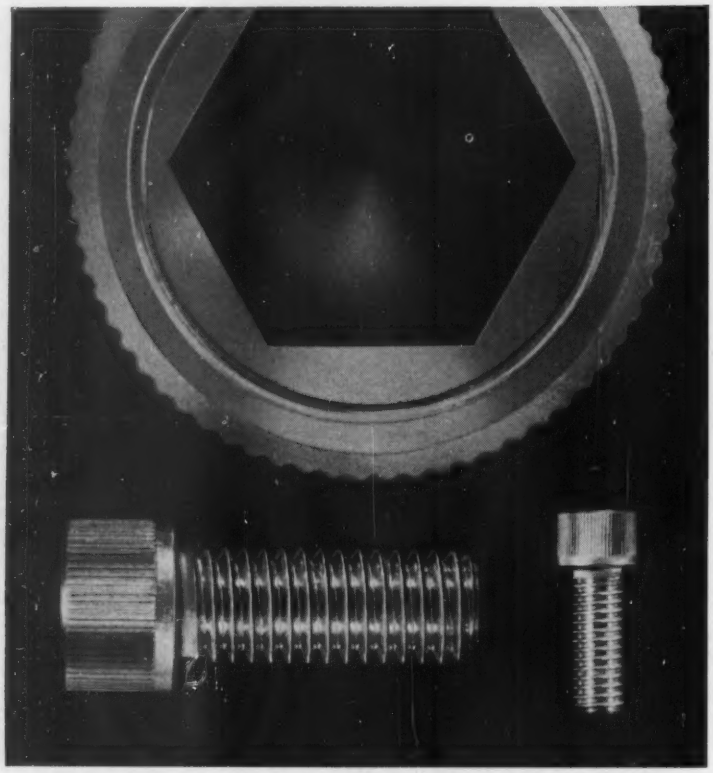
T-J TOMKINS-JOHNSON

RIVITORS...AIR AND HYDRAULIC CYLINDERS...CUTTERS...CLINCHORS

Representation in all major areas, including Canada.

Circle 431 on Page 19

New UNBRAKO stainless socket screws offer 125,000 psi minimum tensile—certified!



Groove around socket identifies UNBRAKO KS 812 stainless tension fasteners, latest in new SPS high-performance K Series. Affidavit certifying 125,000 psi minimum tensile accompanies every lot.

TYPICAL MECHANICAL PROPERTIES
UNBRAKO KS 812 Stainless Socket Head Cap Screws

Test Temp.	-60°F	Room	800°F
Ultimate tensile strength, psi	147,000	131,870	101,400
Yield strength, psi	94,000	80,700	70,900
Shear strength, psi		85,000	
Fatigue endurance, psi		40,000	
Stress relaxation Initial stress 65,000 psi Residual stress after 50 hr			55,000
Magnetic permeability		below 1.05	

Besides high tensile strength, KS 812 offers good shear and endurance properties, adding to overall reliability of your stainless assemblies. New fastener meets or exceeds AMS 7472, FF-S-86.

If you are looking for more fastening strength in your stainless designs (without going to specials) . . . or for ways to reduce size or number of fasteners . . . the new UNBRAKO KS 812 provides an answer. Here at last is a stainless steel socket head cap screw offering a guaranteed tensile strength of 125,000 psi minimum. Yet this precision-forged, burr-free fastener is a standard, available in quantity off the shelf.

To make a corrosion-resistant cap screw that can be certified for 125,000 psi tensile, SPS uses a high-grade austenitic stainless, hardening it through cold working. Heads and sockets are forged; threads are rolled to preserve integrity of grain structure and enhance overall mechanical properties. Also the KS 812 has both the UNBRAKO pHd* head, which gives greater holding power, and the SPS Hi-Life thread root form, which increases fatigue resistance.

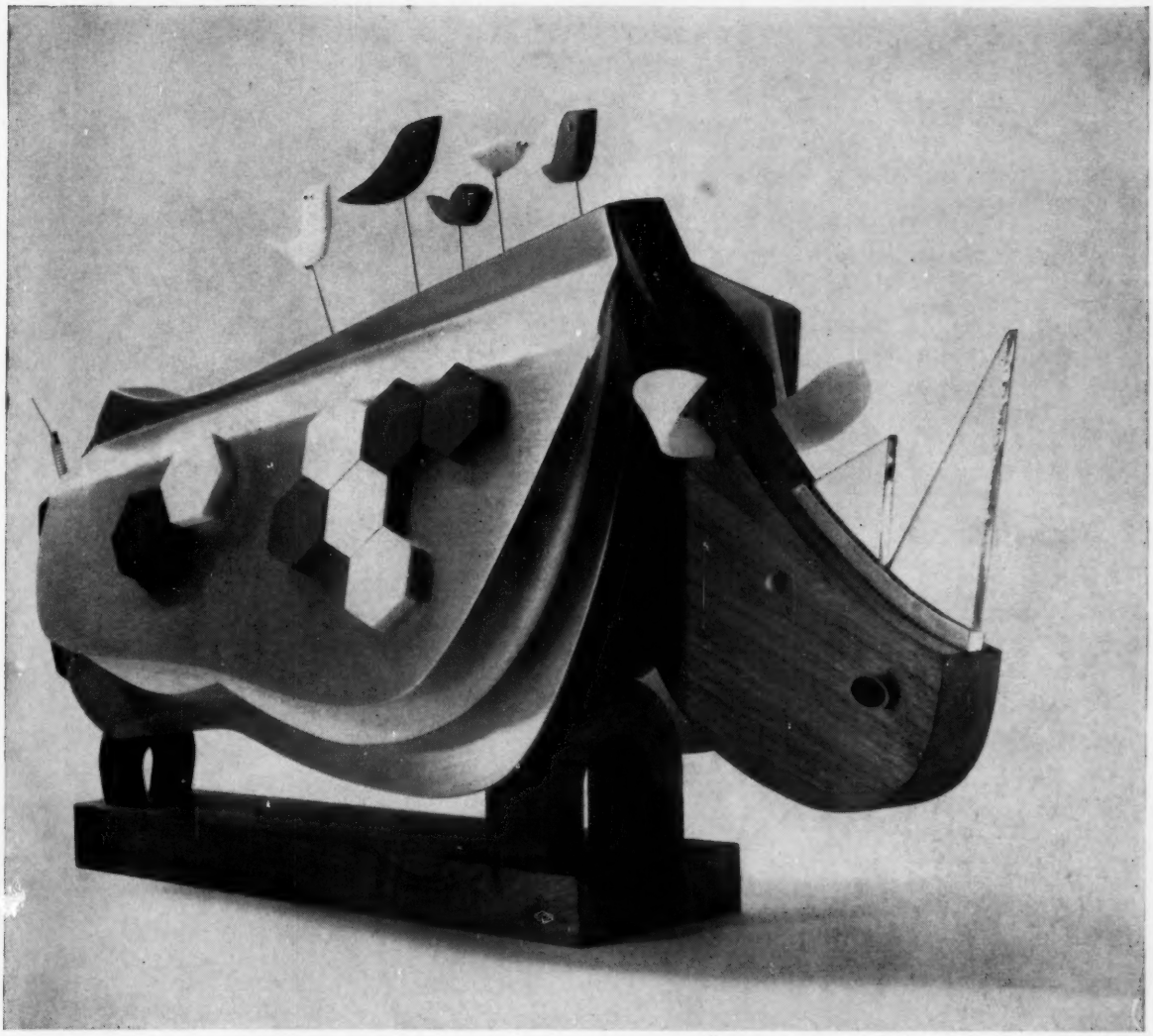
UNBRAKO KS 812 socket screws offer high corrosion resistance over a wide range of applications, as well as low magnetic permeability (under 1.2). Serviceable from —300° to 800°F, they come in sizes #8 through ⅜ in., fine or coarse thread. Ask your UNBRAKO distributor for more details or write Standard Pressed Steel Co. for new Bulletin 2734. INDUSTRIAL FASTENER Division, SPS, JENKINTOWN 18, PENNSYLVANIA.

*proper Head design (1960 series—standard on all UNBRAKO socket head cap screws, as is Hi-Life thread)

SPS

where reliability replaces probability

Circle 432 on Page 19



Sculpture created especially for 3M Company by Guy Palazzola

STRENGTH

. . . Bonds "strong as a bull rhinoceros" made with SCOTCH-WELD®

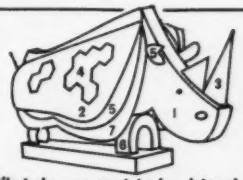
Brand Structural Adhesives

Whatever materials you're bonding (to the same or to another material), a SCOTCH-WELD Brand Structural Adhesive bond will give you a bonus of structural strength at the joint, with the flexibility to resist vibrational fatigue. SCOTCH-WELD adhesive bonds distribute stress loads uniformly, and protect the strength and integrity of the materials by eliminating fastening holes, maintaining the finish, and sealing joints against corrosion.

Fatigue tests show that metal-to-metal joints in Convair's 880 jet transports and Air Force F-102A jet interceptors, bonded with SCOTCH-WELD adhesives, will outlast the metal structure they bond together! In industry, too, SCOTCH-WELD adhesives are finding use in joining hermetically sealed metal shipping containers, multiple piece castings and thinner gauge metals, where tear strength would limit the effectiveness of other joining methods.

Look first to 3M! A pioneer in adhesive research, 3M has developed the widest line of adhesives in the industry. These Technical Service facilities are at your disposal. For an accurate appraisal of how an adhesive can add strength, light weight, production economy, and greater design freedom to your process or product, call your nearest 3M Field Engineer or write to: AC&S Division, 3M Company, Department SBR-31, St. Paul 6, Minnesota.

"SCOTCH-WELD" is a Reg. T.M. of 3M Co. © 3M Co., 1961.



What do you want to bond to what?

The 3M Rhino is fabricated of these materials and bonded with SCOTCH-WELD Brand Structural Adhesives:

1. Wood 2. Aluminum 3. Glass 4. Ceramic
5. Plastic 6. Permanent Magnet 7. Brass

ADHESIVES, COATINGS AND SEALERS DIVISION

MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

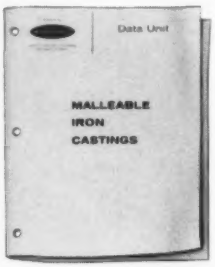
3M COMPANY

New Cars and Trucks Use More Malleable For Better Performance...Lower Cost

As the automotive industry steps up its drive to pack greater performance into lighter weight vehicles and still hold costs in line, the demand for Malleable iron castings continues to increase. Noted for their strength, toughness, machinability and economy, Malleables are used as key components in every make and type of vehicle.

Matching each new advance in automotive technology, Malleable is now available in a broad range of properties, including tensile strengths from 50,000 to 120,000 psi!

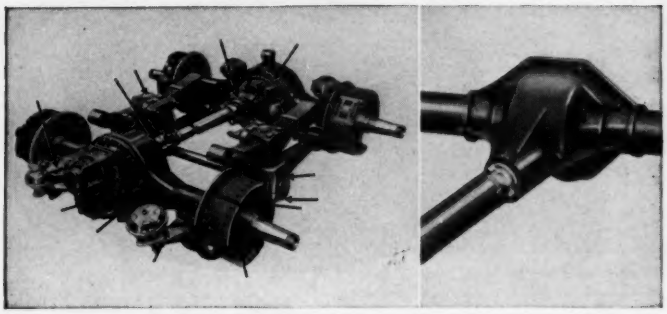
Find out now how much Malleable castings can improve your products. Contact any company that displays this symbol —



For Free Literature on advantages of Malleable iron castings, with examples from the automotive industry, ask any member company for Data Unit No. 113, or write to Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

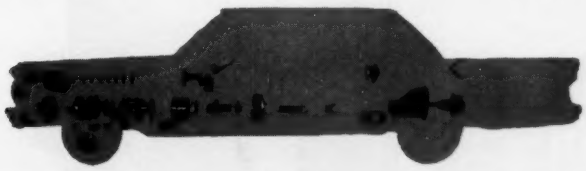
MEMBER
MALLEABLE
CASTINGS COUNCIL

Testifying to Malleable's outstanding ability, pearlitic Malleable iron crankshafts are now used in both cars and trucks, like this new heavy-duty highway hauler. Pearlitic Malleable was chosen for its high strength, wear resistance, damping capacity and machinability . . . Malleable is the most machinable of all ferrous metals of similar properties.



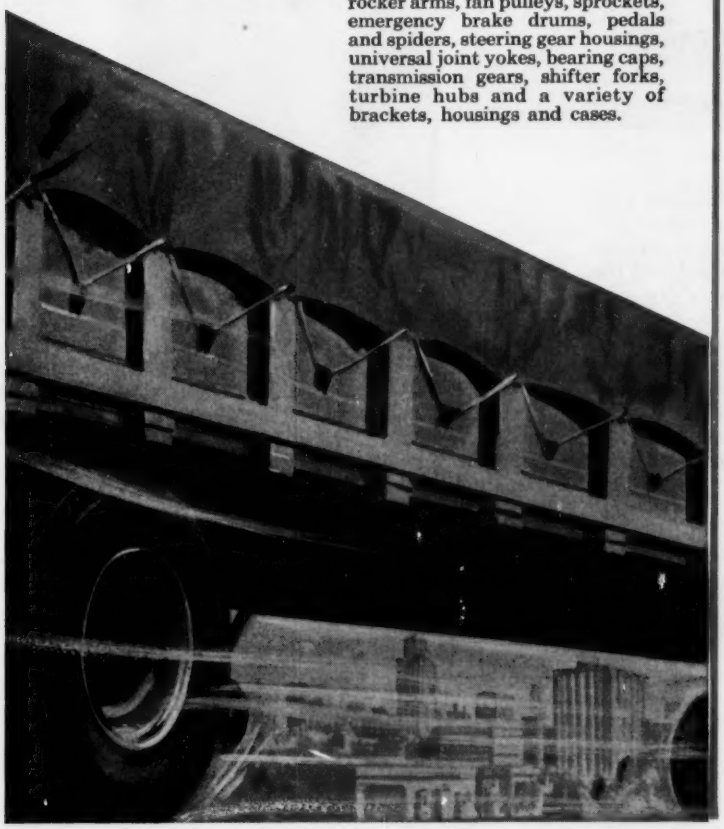
From the smallest cars to the largest trucks, all American vehicles rely on Malleable for a range of uses. In this tandem axle, for example, a total of 36 parts is Malleable.

Malleable differential carriers form the backbone of the rear axles on many new compact cars, as shown at the right above. Tubular steel extensions are pressed into the Malleable housing where they are "puddle" welded. Decisive factors in Malleable's selection were strength, economy, ease of machining and ability to be produced in a design that required a minimum of tooling expense.



The increasing conversion from other materials to Malleable castings for all kinds of parts from crankshafts to door hinges is adding momentum to the automotive industry's steadily increasing use of Malleable.

Among the many Malleable iron castings in this composite car are torsion bar arms and brackets, rocker arms, fan pulleys, sprockets, emergency brake drums, pedals and spiders, steering gear housings, universal joint yokes, bearing caps, transmission gears, shifter forks, turbine hubs and a variety of brackets, housings and cases.



For Quality and Economy Use

MALLEABLE

For Service Contact...

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Connecticut Mall. Castings Co., New Haven 6
Eastern Malleable Iron Co., Naugatuck

DELAWARE
Eastern Malleable Iron Co., Wilmington 99

ILLINOIS
Central Fdry. Div., Gen. Motors, Danville
Chicago Malleable Castings Co., Chicago 43
Moline Iron Works, Moline
Moline Malleable Iron Co., St. Charles
National Mall. and Steel Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Albion Malleable Iron Company, Muncie Division, Muncie
Link-Belt Company, Indianapolis 6
National Mall. & Steel Castings Co., Indianapolis 22

IOWA
Iowa Malleable Iron Co., Fairfield

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
Albion Malleable Iron Co., Albion
Auto Specialties Mfg. Co., Saint Joseph
Cadillac Malleable Iron Co., Cadillac
Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
Northern Malleable Iron Co., St. Paul 6

MISSISSIPPI
Mississippi Malleable Iron Co., Meridian

NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division Eastern Malleable Iron Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

OHIO
American Malleable Castings Co., Marion
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div., Columbus 16
National Mall. and Steel Castings Co., Cleveland 6

PENNSYLVANIA
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Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

TEXAS
Texas Foundries, Inc., Lufkin

WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

WISCONSIN
Belle City Malleable Iron Co., Racine
Chain Belt Company, Milwaukee 1
Federal Malleable Company, Inc., West Allis 14
Kirsh Foundry Inc., Beaver Dam
Lakeside Malleable Castings Co., Racine
Milwaukee Malleable & Grey Iron Works, Milwaukee 46

These companies are members of the Malleable Castings Council

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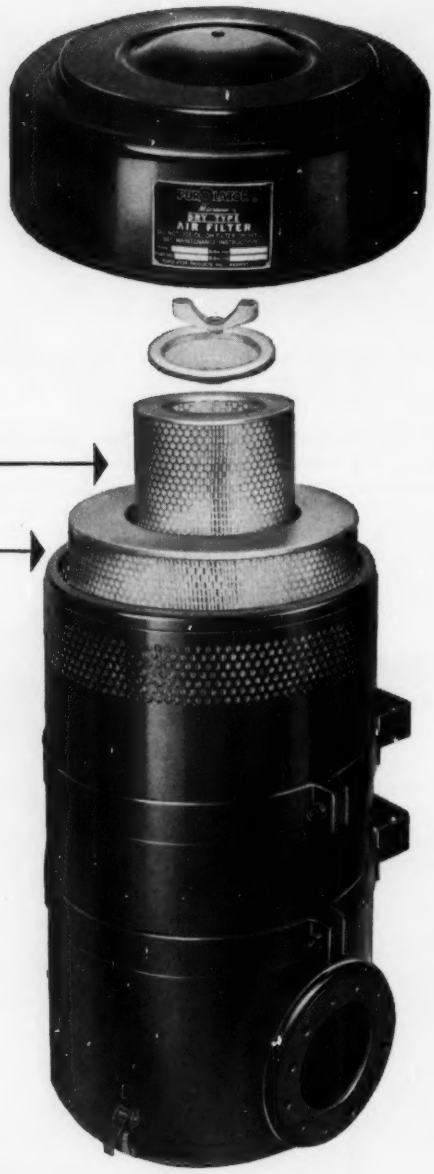


an element here

and an element here

assures 99.98% filtration efficiency even when 1 element is out of operation

IT'S THE NEW PUROLATOR TWO-STAGE FILTER

Simplicity of design makes the first cost of Purolator's new dry-type two-stage filter as low as any two-stage filter on the market. Each element filters independently, and together they dustproof your engine as no other filter can . . . 99.98% efficient.

Users save money and get better engine protection from this new Purolator filter, too. The first stage element will last up to 2000 hours, depending on operating conditions. The second stage will usually last almost indefinitely if the first element and sealing gaskets are maintained properly.

Another big user-advantage is the way the two-stage design protects the engine despite accidental mishandling of the element. Even if the first stage element is damaged, the chance of harming the engine can be discounted when it is protected with the second stage back stop element. In addition, the second stage element lets the operator service the unit in the field, regardless of how dusty the conditions are.

Both elements filter uniformly, in depth, over their whole surface, because they're both precision made of plastic impregnated cellulose. This series of two-stage filters is rated from 450 to 1150 cfm, with exceptionally low initial restriction. Mounting straps, rainhoods and outlet adapters are available.

For more information write to Purolator Products, Inc., Department 3896, Rahway, New Jersey.

Purolator Products, Inc.
Dept. 3896, Rahway, New Jersey

Please send me complete data on the new Purolator two-stage filter series.

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

Filtration For Every Known Fluid

PUROLATOR

PRODUCTS, INC.

RAHWAY, NEW JERSEY AND TORONTO, CANADA

Circle 435 on Page 19

R B & W FASTENER BRIEFS

RUSSELL, BURDSALL & WARD BOLT AND NUT COMPANY

Technical-ities

By Fred E. Graves

Fastening of joints in corrosive environment

For a fastener to stand up in a corrosive environment it must either be coated, or made from an anti-corrosive metal.

THE METALLIC COATINGS

The "workhorse" applications are satisfied most economically with SAE Grade 2 or Grade 5 fasteners. Required outdoor durability is achieved with a plated or a hot galvanized finish. Hot galvanizing complicates good thread fits, costs more than plating in the popular size range, but gives much greater protection than any commercial plating.

A heavy galvanized coating is not recommended on highly stressed fasteners. If you need the high strength of Grade 5 bolts and want them corrosion-resistant, zinc plating should be your first choice. Certain conditions may require cadmium, nickel or copper plate.

THE ENDURING METALS

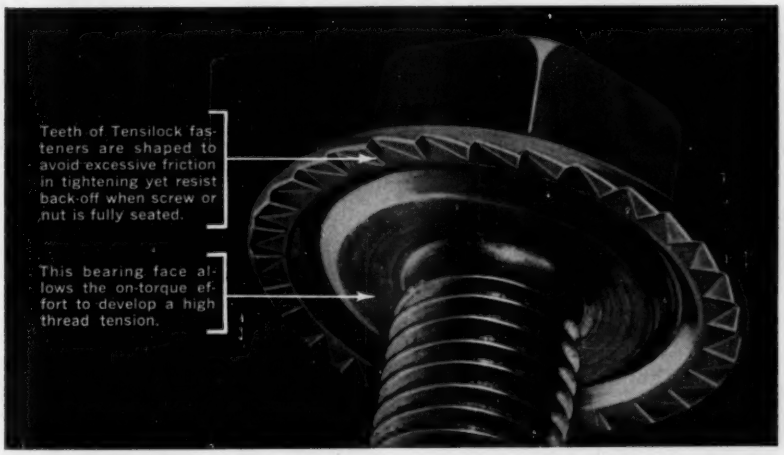
While each metal poses problems in certain applications, stainless steel, aluminum, and silicon bronze all offer distinct advantages.

Silicon bronze is popular for electrical uses due to its unusual strength, resistance to stress-corrosion, good conductivity.

Aluminum fasteners afford light weight as well as excellent conductivity. Anodized, they provide various colors; better corrosion resistance.

Widely used for fasteners, the 18-8 grade stainless steel assures good strength and excellent corrosion resistance in most atmospheres.

How Tensilock® Screws clamp tight, lock tight


Teeth of Tensilock fasteners are shaped to avoid excessive friction in tightening yet resist back-off when screw or nut is fully seated.
This bearing face allows the on-torque effort to develop a high thread tension.

TENSILOCK screws belong in the same league as high strength hex screws. With the same on-torque effort, the Tensilock units develop about 90% of the thread tension usually developed by the latter. Thus, they *both* make strong joints.

THREAD TENSION = CLAMPING FORCE

In theory, the higher the thread tension, the stronger the joint and the higher the inherent ability of the fastener to stay tight. In practice,

Screw Diameter		¼	⅜	½
Thread Tension (lbs.)	Tensilock	2,750	6,750	12,400
	High Strength Hex	2,975	7,250	13,300
On Torque (inch lbs.)	Both	120	420	1,000
Off Torque (inch lbs.)	Tensilock	150	525	1,250
	High Strength Hex	95	330	800

you derive these benefits by torquing a high strength screw close to its *yield strength*. But what if you need high thread tension plus *extra* assurance that joints will stay tight? Then you have a job for Tensilock units. Not only do they develop the high thread tension, but also have an extra (and *integral*) locking device.

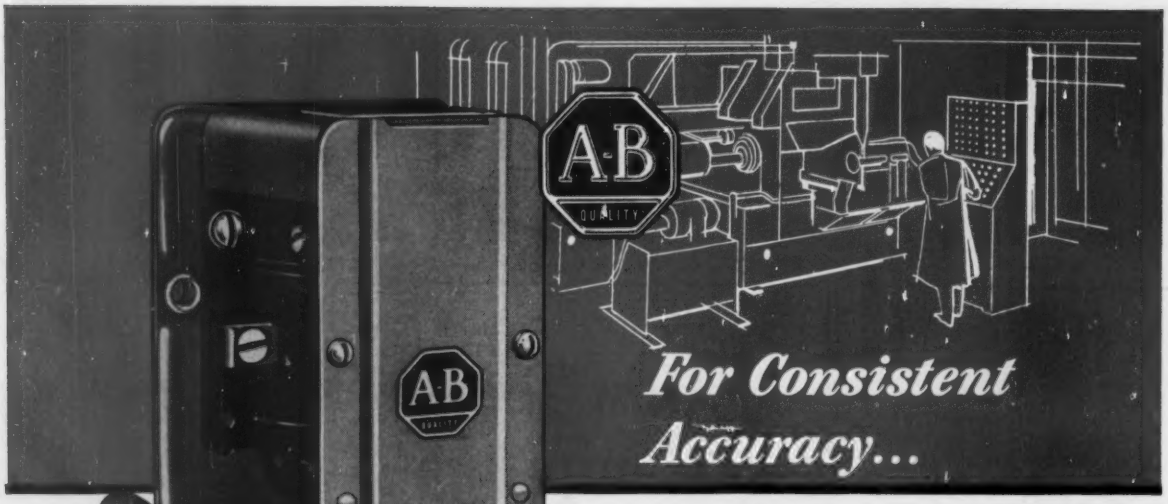
OFF-TORQUE = LOCKING POWER

By design, loosening torque of Tensilock fasteners exceeds tightening torque by 25% or more. This is an effective "lock." It gives that extra margin of safety against vibratory loosening.

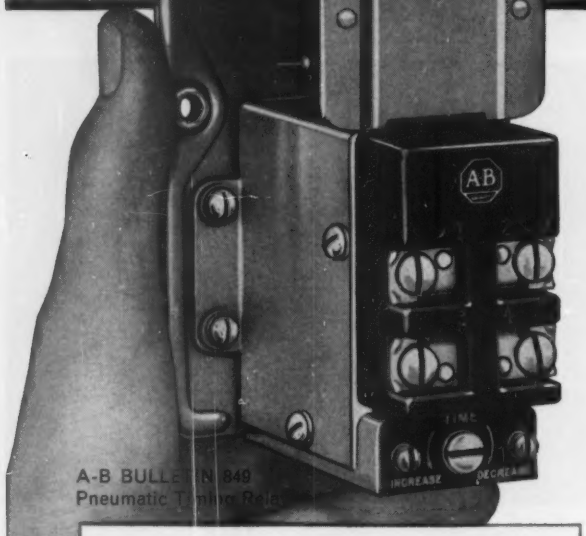
To sum up: RB&W's Tensilock screws are stronger than Low Carbon Hex Screws; compare with High Strength Hex Screws in clamping force; are superior to them in locking action. Suggestion: For a strong locking *bolt*, use with Tensilock Nut. Send for Bulletin TL-2. Russell, Burdsall & Ward Bolt and Nut Company, Port Chester, N. Y.

Plants at: Port Chester, N. Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. Sales office and warehouse at: San Francisco, Calif. Additional sales offices at: Ardmore (Phila.), Pa.; Pittsburgh; Detroit; Chicago; Dallas.

Circle 436 on Page 19

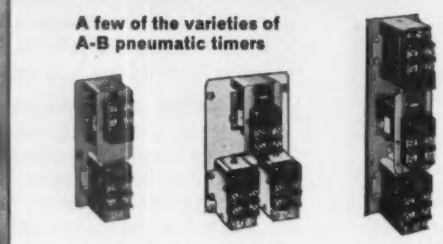


For Consistent Accuracy...



A-B BULLETIN 849
Pneumatic Timing Relay

A few of the varieties of A-B pneumatic timers



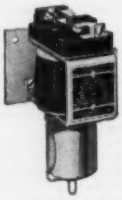
Single operation time delay relay | Dual operation time delay relay | Compound operation time delay relay

Allen-Bradley makes a broad line of timing relays to satisfy all automatic processes.

Specify ALLEN-BRADLEY TIME DELAY RELAYS

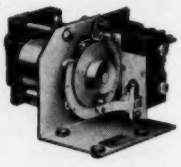
For maximum production, high-speed automatic processes demand that the required operations "start" and "stop" at the correct instant, time after time—*without variation*. For consistent accuracy and trouble free operation, no timing relay on the market can equal the performance of A-B Bulletin 849 pneumatic timers. The delay period can be varied from 1/20 of a second to 3 minutes, and the setting will hold with an accuracy of ± 10%. Conversion from ON-DELAY to OFF-DELAY (or vice versa) is simple—no adjustment is necessary. Like *all* A-B control, these quality timers have maintenance free, double break, silver contacts. The two sets of contacts—one N.O. and one N.C.—are electrically independent, for greater control flexibility. Also, auxiliary contacts can be easily added.

To make certain of a completely satisfactory electrical installation, specify Allen-Bradley "quality motor control"—in addition to the Bulletin 849 pneumatic timing relays. Write for details, today.



BULLETIN 848
Fluid Dashpot
Timing Relay

BULLETIN 852
Electronic
Timing Relay



BULLETIN 850
Motor Driven
Process Timer

ALLEN-BRADLEY

Member of NEMA

Quality Motor Control

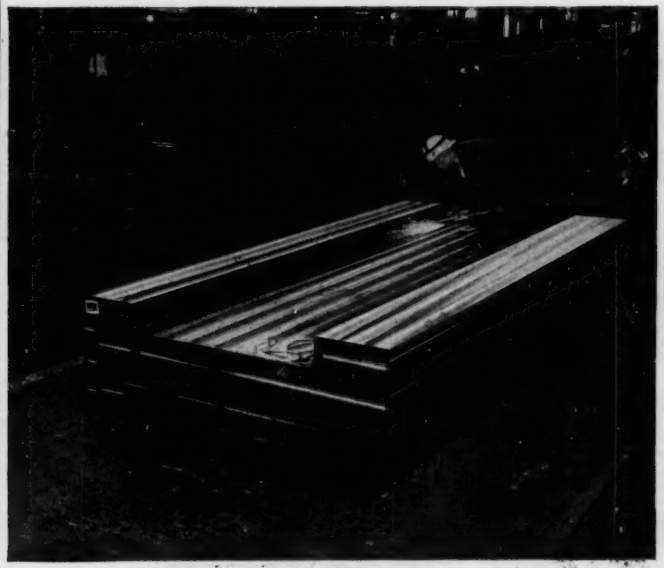
Allen-Bradley Co., 1333 S. First St., Milwaukee 4, Wis. • In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

Circle 437 on Page 19

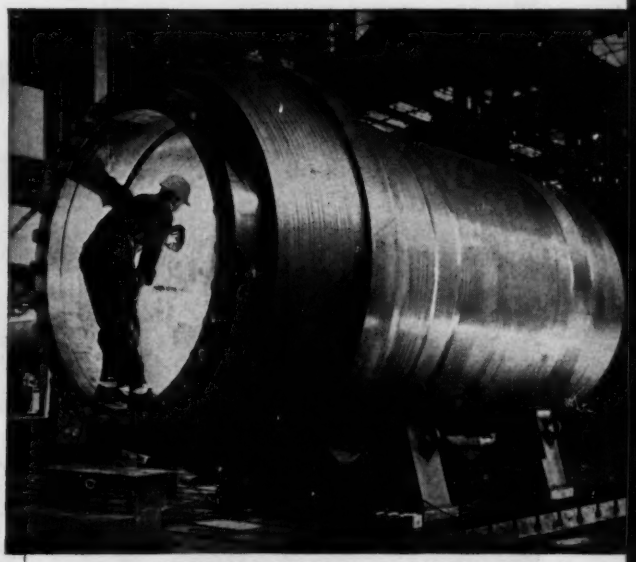
You name it... we'll forge it!

RIGHT ON THE NOSE. Bethlehem meets your specifications exactly on all types of press, drop, and hammer forgings.

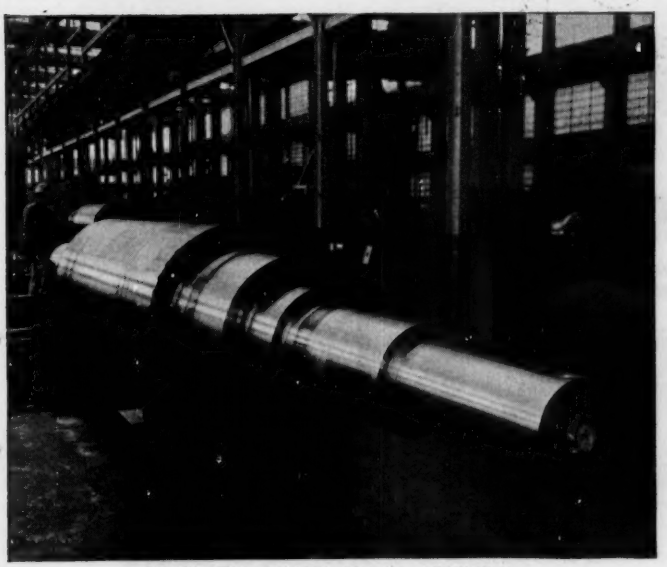
for Strength
... Economy
... Versatility



RAM ADAPTER. This forging weighs 58,780 lb, and measures 140 in. x 73 in. x 25 in.



STEEL CYLINDER for use in 7,500-ton plate stretcher. This forging weighs 171,240 lb, and it's 17 ft, 3 in. long.



GENERATOR SHAFT. Weight, 198,240 lb. As you can tell from these photos, Bethlehem is well-equipped for machining.

REACTOR VESSEL CLOSURE. The OD of this 50,660-lb forging measures 12 ft.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

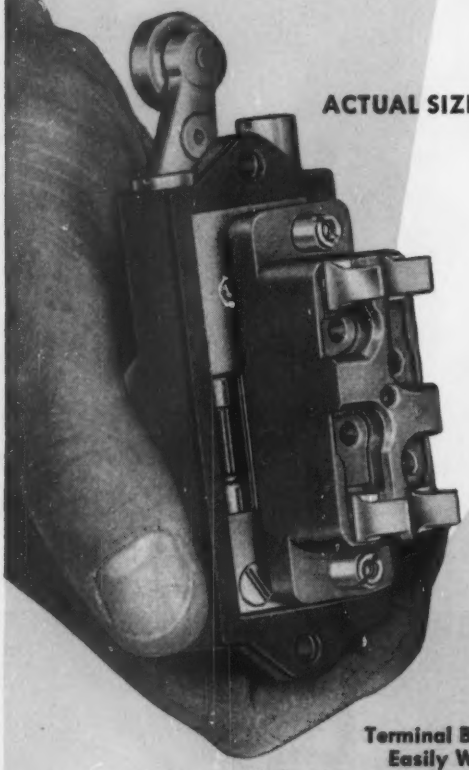
BETHLEHEM STEEL

BETHLEHEM STEEL

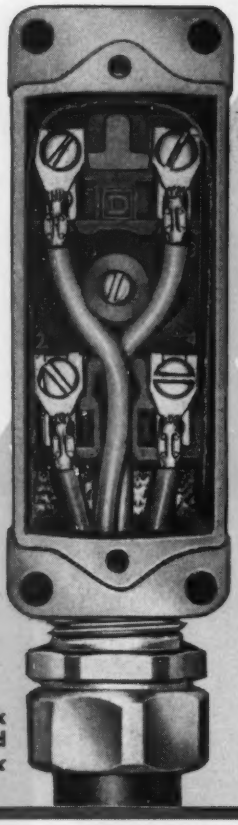
Circle 438 on Page 19

This New *PLUG-IN* LIMIT

CLASS 9007, TYPE AW



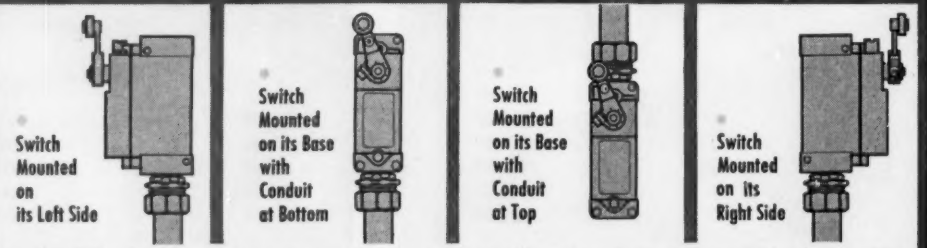
ACTUAL SIZE



Terminal Block Easily Wired ***Without Removing from Box***

- Oil-tight construction
- Switch plugs in—in seconds
- Mounts without disassembly
- Wired without removing from box
- Reversible plug-in unit —can be plugged-in with roller arm at either end
- Switch action can be reversed by simple screwdriver adjustment
- Present installations easily converted to plug-in
- Precision switch mechanism —only 5° to operate— 25°overtravel in either direction
- Graduated markings around hub of roller arm simplify accurate settings
- Same price as standard Square D oil-tight limit switch

6 MOUNTING ARRANGEMENTS...WITH 1 DEVICE!


Switch Mounted on its Left Side
Switch Mounted on its Base with Conduit at Bottom
Switch Mounted on its Base with Conduit at Top
Switch Mounted on its Right Side

In any of the above arrangements, conduit can enter at either top or bottom by reversing box position

SQUARE D COMPANY

wherever electricity is distributed and controlled

SWITCH is SO EASY to Use!

SQUARE D LIMIT SWITCHES ARE Designed TO DO HUNDREDS OF JOBS — BETTER!

SMALL OIL-TIGHT LIMIT SWITCH -- CLASS 9007, TYPE AW

Surface mounting, roller arm operated

Surface mounting with angular adjustable roller arm

Surface mounting push rod operated with micrometer adjustment

Roller plunger operated with micrometer adjustment

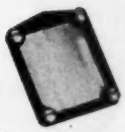
Duplex switch, flush mounting, lever arm operated

Flush mounting, lever operated

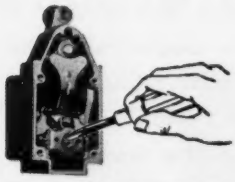
ROLLER ARMS AVAILABLE IN WIDE RANGE OF DESIGNS AND LENGTHS...

HEAVY-DUTY OIL-TIGHT LIMIT SWITCH -- CLASS 9007, TYPE T

Continuously adjustable lever arms, up to 80° overtravel



Transparent plastic cover available for instant inspection

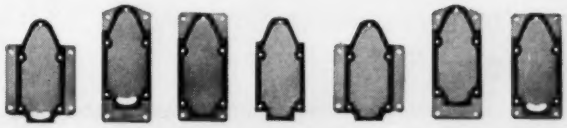


Eleven contact arrangements in one switch; only a screwdriver is required

Rear shaft design for inaccessible locations

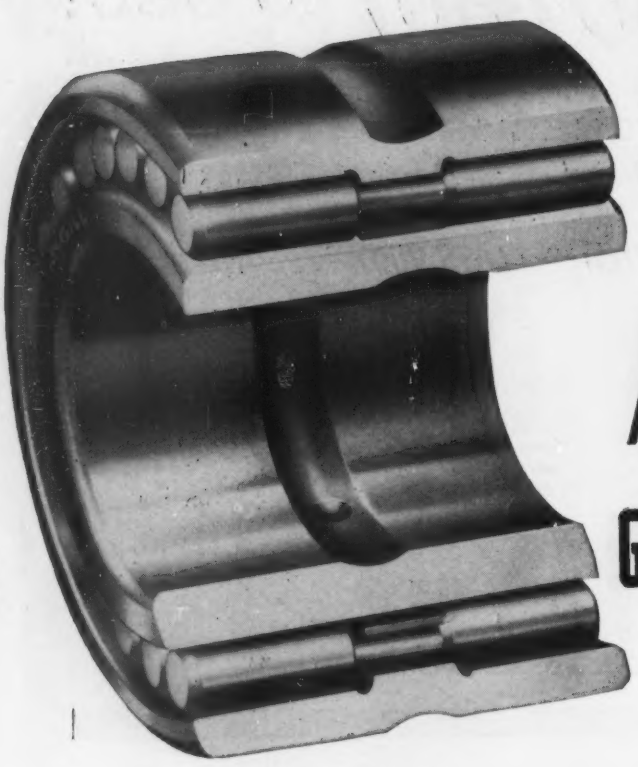
Many sizes and types of operating arms

WIDE VARIETY OF BASE PLATES AND MOUNTING HOLES...



Write for BULLETIN 9007 AW to Square D Company, 4041 North Richards Street, Milwaukee 12, Wisconsin

FOR EXTRA LOAD CAPACITY IN MINIMUM RADIAL SPACE use



McGILL®

GUIDEROL® BEARINGS

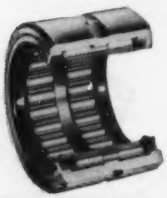
MT SERIES

Here is a compact bearing with high load-carrying capacity. Its full complement of race-width rollers is guided by an integral rail in the outer race bore, providing strength and skewing limitation that prevents binding under controlled misalignment. Rollers are guided at any operational angle from horizontal to vertical — self-cleaning through open ends. Available with or without separate inner ring in shaft sizes from ½" to 9¼". Dimensionally interchangeable with ordinary heavy duty needle bearings.

CT SERIES

Offer full type roller bearing capacity dimensionally interchangeable with ball and cylinder roller bearings of single and double row dimensions. The inner ring may be eliminated for further reduction of radial space.

SEALED—AND STILL COMPACT



No extra axial space needed for the sealed SG series GUIDEROL bearing. Seals are press-fitted securely in the outer race bore to provide the same width and performance advantages of standard GUIDEROL bearings. Contaminants are locked out, lubricants sealed in for those hard to re-lubricate applications. The SG series solves the problem of too-expensive auxiliary sealing assemblies.

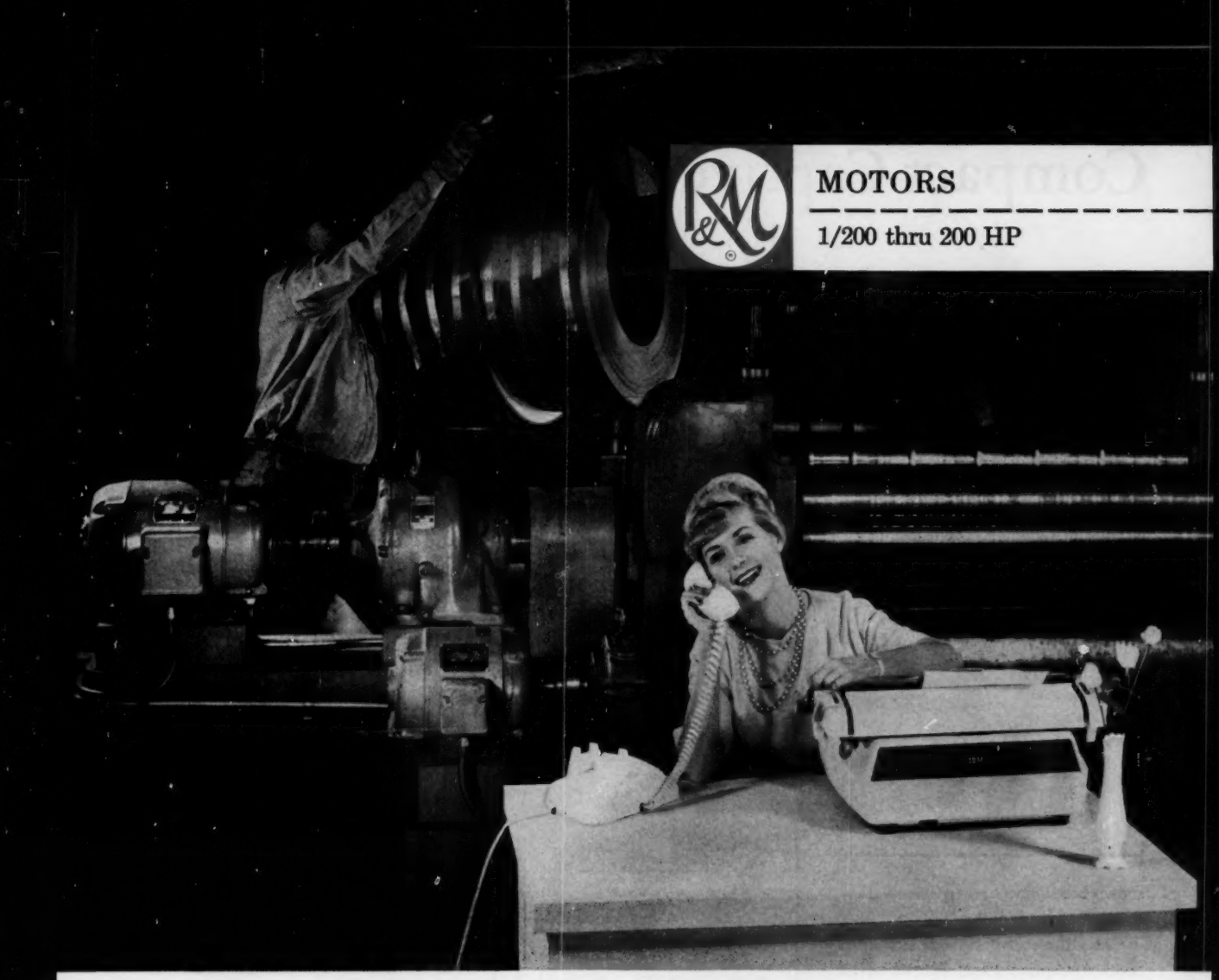
Write for McGill's Bearing Catalog #52-A, for engineering data with dimensional and capacity information on McGill needle type roller bearings. Ask about special precision ball and roller bearings.

McGILL MANUFACTURING CO., INC., Bearing Division
200 N. Lafayette Street, Valparaiso, Indiana

engineered electrical products

McGILL®

precision needle roller bearings



MOTORS

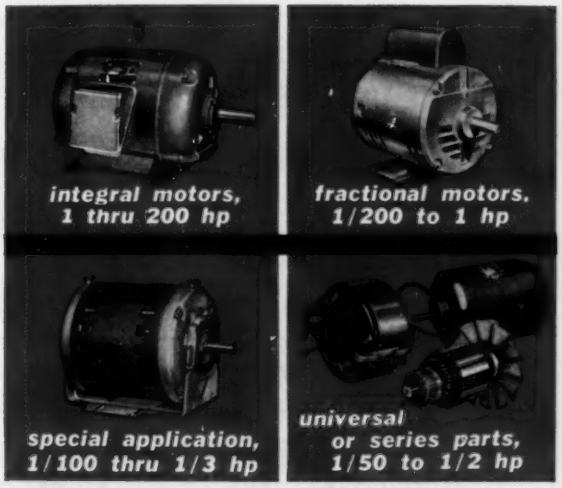
1/200 thru 200 HP

from machine tools to typewriters . . .

. . . Robbins & Myers motors power them all!

Each R&M motor, 1/200 through 200 HP, is electrically and mechanically designed with life-prolonging features which assure dependable operation, simplified installation and low maintenance. From rugged machine tools to complex business machines, there's an R&M motor for every job . . . Fractional and Integral H.P. Motors and Motor Parts in all popular mountings, electrical types and enclosures. Most are ready for off-the-shelf delivery. Others can be quickly produced. Should you require custom motors, R&M's experienced application engineers, aided by modern electronic computers, can furnish the one design best suited to your needs.

Write today for information, or send your powering problem to R&M. No obligation, of course!


integral motors, 1 thru 200 hp
fractional motors, 1/200 to 1 hp
special application, 1/100 thru 1/3 hp
universal or series parts, 1/50 to 1/2 hp

ROBBINS & MYERS, INC., Springfield, Ohio

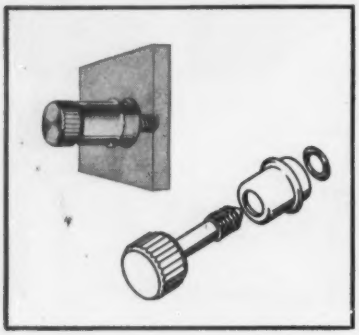
Fractional and Integral HP Electric Motors • Electric Hoists and Overhead Traveling Cranes • Moyno® Industrial Pumps
Propellair® Industrial Fans • R & M-Hunter Fans and Electric Heat • Trade-Wind Range Hoods and Ventilators
Subsidiary companies at: Memphis, Tenn., Pico Rivera, Calif., Brantford, Ontario.

Circle 441 on Page 19

Compact Captive Panel Screws:

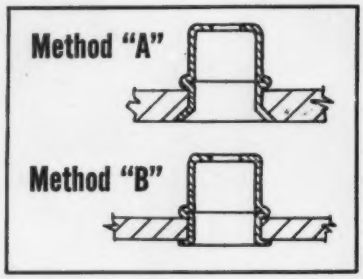
Standard Design Lowers Installed Costs

No longer is it necessary to resort to a costly fastening device of special design to provide quick attachment and release of electronic components. Standard Southco Retractable Screw Fasteners (stand-off thumb screws), available from stock, are both fast to install and economical. The five sizes,

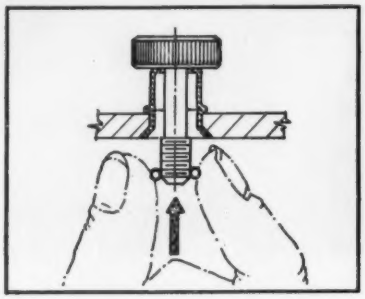


shown below, meet a very wide variety of requirements.

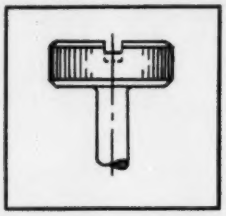
Check these advantages of simplified Southco Captive Panel Screws. Even when many screws are in one panel, misalignment is easily handled because the screw floats in a large hole in the stand-off, allowing ample play for "lining up." No special tools are



needed for installation, thus production is not subject to tool failure, nor limited by either the number of special tools available or the number of personnel trained in their use.



The Southco No. 58 Retractable Screw Fastener consists of three parts: thumb screw, stand-off, and retaining ring. The bright nickel-plated brass stand-off is inserted in either a drilled and countersunk hole (Method A), or a drilled hole (Method B), and flared. The polished, chrome-finished brass screw is passed through the hole in the stand-off and made captive by a retaining ring. Engaging in a tapped hole in the frame, the screw may be fully withdrawn without moving the panel, yet always is retained.



The unslotted screw is standard in ¾", 9/16", and 7/16" head diameters and three thread sizes. Slotted head screws are also available in all sizes. The stand-off is standard in sizes to fit panel thicknesses from a minimum of 1/16" to a maximum of 17/64". Screw and stand-off are also obtainable in stainless steel.

MINIATURE TO LARGE SIZE HEADS IN FIVE TYPES

HEAD DIAMETER	3/4"	9/16"	9/16"	7/16"	7/16"
THREAD SIZE	1/4-20	1/4-20	12-24	10-24	10-32

Free Fastener Handbook

Send for your complete Southco Fastener Handbook, just printed. Write to Southco Division, South Chester Corporation, 237 Industrial Highway, Lester, Pa.

SOUTHCO FASTENERS

LION

©1959

This Sandusky Centrifugal Casting—one of four produced for Westinghouse Atomic Equipment Department—meets radiographic, intergranular corrosion, and all other rigorous chemical and physical tests.

ONE SANDUSKY CENTRIFUGAL CASTING ...makes 4 giant stator shells

Specified by Westinghouse for 4 canned motor pumps soon to be integral parts of reactor system in Yankee Atomic Electric Plant in Rowe, Massachusetts

One king-size 17-ton Sandusky casting supplied the main motor bodies (stator shells) for the four pumps being built by Westinghouse, each to handle 23,600 g.p.m. of pressurized water through the reactor core.

The 25-foot-long Sandusky casting was centrifugally spun of a modified CF-8 (Type 304 L) stainless steel, then machined by Sandusky to a 3" wall thickness, 31½" on the O.D. This huge casting was hydrostatically tested to 3800 psi before being sectioned into four 68" lengths.

These stator shells represent another *new and exacting application* for Sandusky Centrifugal Castings—which may offer a practical and economical answer to *your* cylindrical requirements also. They are available in diameters from 7" to 54"—in lengths up to 33 feet—in heat- and corrosion-resistant stainless, carbon and low-alloy steels and a wide range of copper-base and nickel-base alloys.

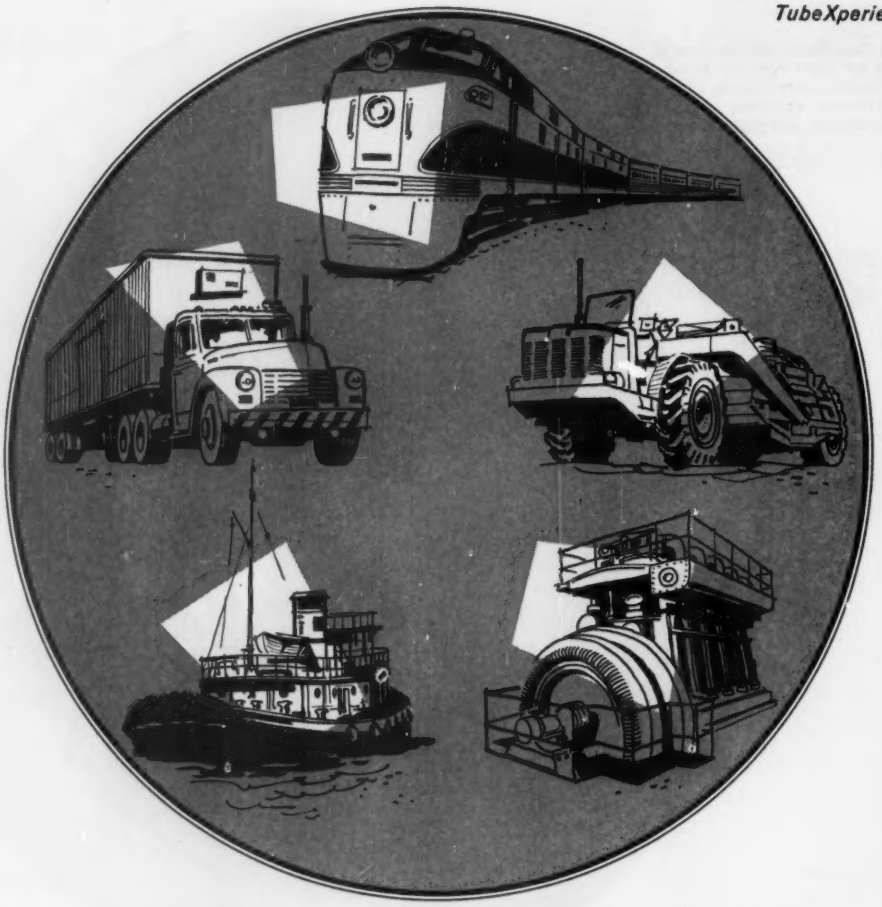
Let us show you how Sandusky Centrifugal Castings can help solve your cylindrical problems. Write to us at Sandusky, Ohio.

SANDUSKY ® **CENTRIFUGAL CASTINGS**

SANDUSKY FOUNDRY & MACHINE CO.

SANDUSKY, OHIO Stainless, Carbon, Low-Alloy Steels—Full Range Copper-Base, Nickel-Base Alloys

Circle 443 on Page 19



Feedlines for hungry horsepower . . . diesel fuel injection tubing by Superior

Fuel injection systems are the heart of thousands of diesel-powered trucks, locomotives, roadbuilding equipment, electric generators, and marine power plants. The tubing that conveys the fuel from injection pump to nozzle assembly is an important component. It must resist the stresses of pressure and vibration, yet be ductile enough to be cold swaged and upset and be cold formed into loops and bends without excessive springback. It must have a clean ID, tremendous burst strength, and high fatigue resistance. Superior diesel fuel injection tubing is just such a premium product.

Type C-1008 and Type MT-1010 carbon steel tubing are most commonly specified for this application, but alloy and stainless steel tubing for pressures above 9000 psi and greater corrosion resistance is available. Superior also makes tubing for many other applications—supplies both general and special purpose tubing for aircraft, missiles, electrical, electronic, chemical, hydraulic, dairy and nuclear, to name a few. For complete information, write Superior Tube Company, 2010 Germantown Ave., Norristown, Pa.

SOME REASONS WHY SUPERIOR FUEL INJECTION TUBING IS A PREMIUM PRODUCT

- It will handle pressures to 9000 psi, is hydrostatically tested to various pressures according to specification
- It is cold drawn, dead soft annealed, and seamless
- It is ID conditioned to remove fissures and other defects
- It is free from ID radial cracks deeper than .005 in. or 5% of wall thickness, whichever is less
- It is annealed at finish in controlled atmosphere furnaces to produce a soft, ductile and scalefree material
- Fracture tests are performed when requested

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

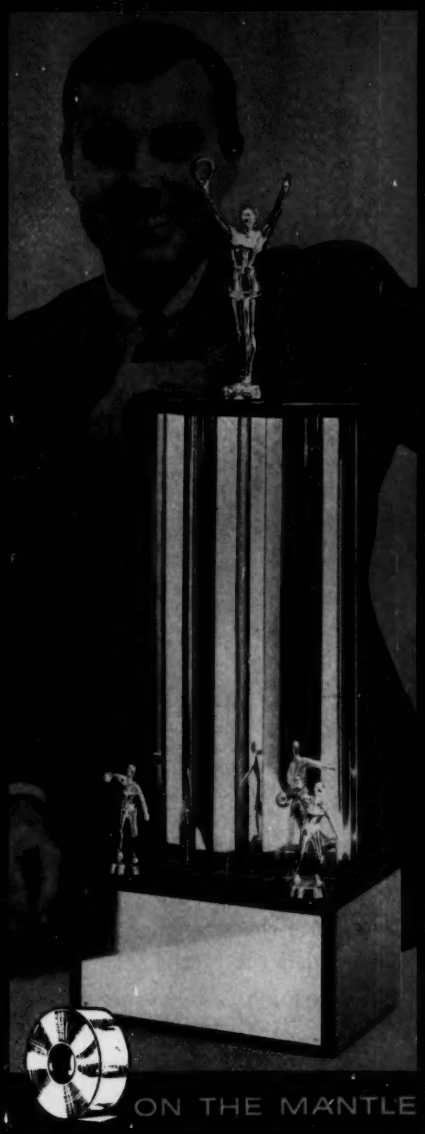
All analyses .010 in. to 3/8 in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

Circle 444 on Page 19

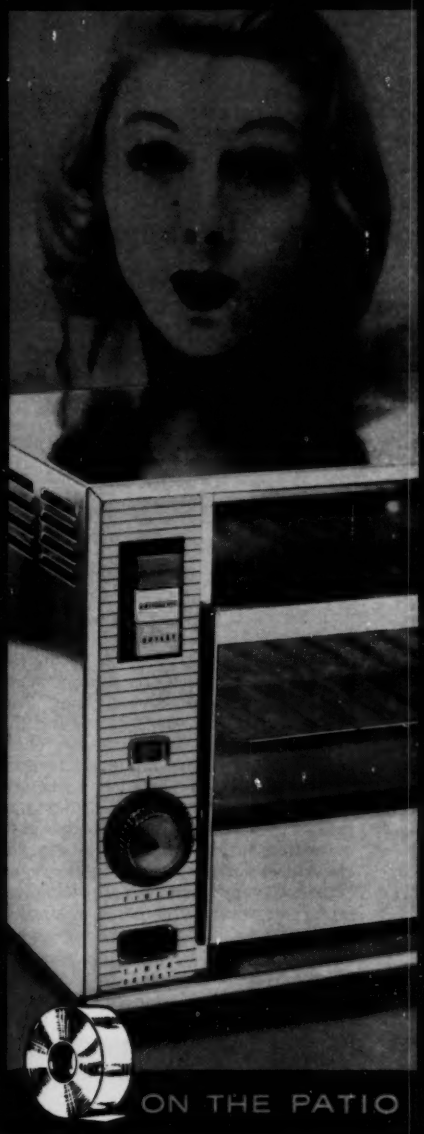
Circle 445 on Page 19→

NICKELOID IS EVERYWHERE



ON THE MANTLE

ON CARPETING



ON THE PATIO

These eye-catching products use functionally a basic Nickeloid Metal. The finish of Chromium, Nickel, Brass or Copper is electroplated to a base metal, usually Steel (but often Zinc, Brass or Copper).

Mostly, Nickeloid Metals are supplied in continuous coils in widths up to 24" for modern, low cost fabrication. They're also available in sheets and strips. Optional: bright or satin finishes, plating one or both sides, a galaxy of stunning patterns and crimps.

Quality plating produces metals so durable they can be fabricated, even quite severely drawn or bent. Rejects minimized. For severe stamping, we offer Mar-Not protective coating that is easily peeled off after its job is done.

Which is your preference in modern metals — the clean, flint-hard gleam of Chromium, the warmth of Copper, or the rich radiance of polished Brass? No need to answer now, but consider the galaxy of wonderful products you find everywhere today that employ one of the Nickeloid Metals. These durable, lustrous finishes are not mere lily-gilding. In most instances they are designed INTO the product . . . functionally. We make a raw material that has been given these quality finishes the *automated* way . . . in giant coils in block-long mills. Nickeloid finishes are electroplated to the base metal *before fabrication*, a process as fundamental we believe as the coating of printing papers in rolls *before they are printed*. Three out of five costly manufacturing steps are by-passed. Write for our free Introductory Kit, which includes metal samples — learn the complete story.

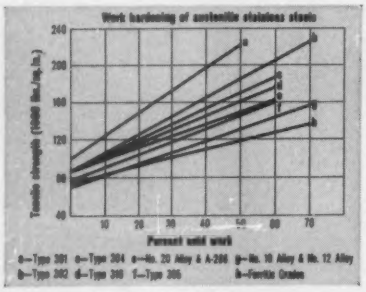
AMERICAN NICKELOID COMPANY · PERU 8, ILLINOIS

America's Pioneer Manufacturer of Pre-Finished Metals — Since 1898

Design engineers demand versatility ...they get it with Stainless Steel

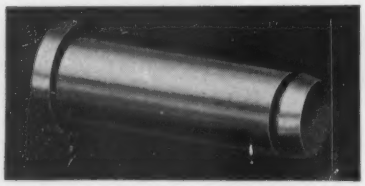
Design Engineers constantly search for materials that will serve in a wide range of applications. Here's why Carpenter Stainless Steels offer the versatility required to produce new products and improve present designs.

Cold heading applications


Work hardening of austenitic stainless steels
Tensile strength (1000 lbs./sq. in.)
Percent cold work
a—Type 301 c—Type 304 e—No. 20 Alloy & A-286 g—No. 10 Alloy & No. 12 Alloy
b—Type 302 d—Type 316 f—Type 305 h—Ferritic Grades

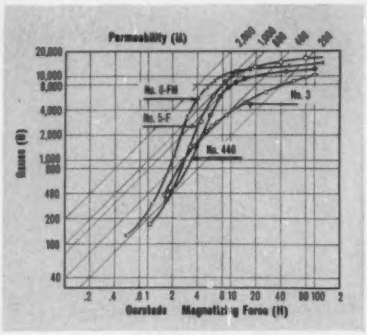
The relative cold headability of austenitic stainless and heat resisting steels is determined by their respective work hardening rates. Alloys showing the least amount of increase in hardening per given degree of cold work need less work to form them. They thus cause less tool wear. Curves for the austenitic grades in the above chart show that Type 305 stainless, a grade often used for cold headed parts, has a much lower work hardening rate than Types 304 and 316. It also indicates that Stainless No. 10 and No. 12, special stainless steels produced by Carpenter, have even lower work hardening rates than Type 305, only slightly higher than rates for the ferritic grades such as Type 430.

Production cost cut 50%



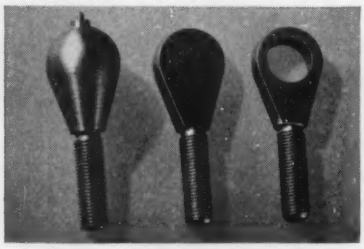
The switch to Carpenter Stainless No. 8 (Type 303) for these dishwasher hinge pivot pins increased production, improved quality and provided a cost saving of 50% per part. Tool regrinding was substantially reduced, size tolerances were accurately held and final grinding operations were completely eliminated. Along with these benefits, this customer received excellent corrosion resistance and brilliant finishes . . . two vital requirements for the successful production of this part.

Magnetic core applications

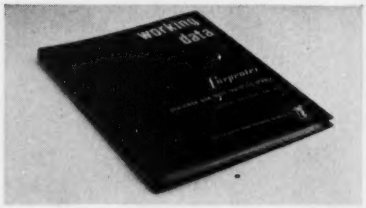


Four Carpenter Stainless Alloys are available for magnetic core applications that must operate for long periods in highly corrosive media. All four are produced to special quality standards that assure consistent uniformity in magnetic behavior. This magnetic behavior of stainless steels varies with their hardness. For consistency and best magnetic properties, the alloys should be in the fully annealed condition after all machining operations. The chart above shows the magnetization-permeability characteristics of Carpenter No. 3, No. 5-F, No. 6-FM, and No. 446 as annealed.

One change... five benefits



Original specifications for this missile part called for heat treated alloy steel with a tensile strength of 125,000 to 145,000 psi. With the AISI 4130 steel selected for this part, the required finish could not be obtained consistently on either the threading, milling or reaming operations. Another major problem was the 25% reject rate, caused by cadmium build-up on feathered edges of the threads after plating. A request for a specification change resulted in the switch to Carpenter No. 5 (Type 416) and here's what happened! Production increased 55% . . . rejects dropped from 25% to 0 . . . cadmium coating was no longer required . . . grinding was eliminated . . . delivery requirements were easier to meet.



New 180-page working data book on Carpenter Stainless and Heat-Resisting Steels. Includes descriptions of all grades, information on selection, fabrication tips, corrosion tables and application data. Ask your Carpenter Representative, or write for a copy.

Are you getting all these performance characteristics in the materials you specify?

- ☐ *brilliant finish*
- ☐ *maximum strength*
- ☐ *corrosion resistance*
- ☐ *uniformity*
- ☐ *hardness*
- ☐ *versatility*
- ☐ *good machinability*
- ☐ *ease of fabrication*
- ☐ *exacting tolerances*
- ☐ *long service life*
- ☐ *customer satisfaction*

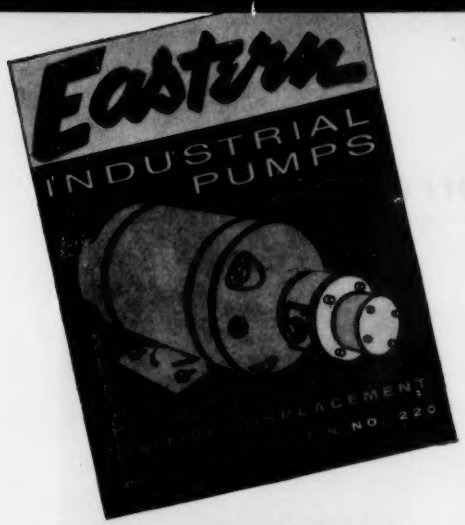
Carpenter Stainless gives you *all* these . . . and more!

Carpenter steel

you can do it ***consistently*** better with Carpenter Stainless Steels for specialists

Stainless Steel

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.



EASTERN takes the gamble out of selecting

POSITIVE DISPLACEMENT PUMPS

If you have a performance requirement for pumps which can deliver a pulsation-free flow of non-lubricating liquids at pressures up to 200 psi on the gear type or rates up to 6 gallons per minute on the vane type, pick a winner from the big Eastern line.

For small volumes against relatively high pressures, the Eastern GW series gear pumps are a natural. In each pump, oversized bearings of impregnated graphite support a drive gear of stainless steel and an idler of special bronze material. These self-priming units require no lubrication and cannot contaminate the liquid being pumped.

For volumes from 1.5 to 6 gpm and pressures to 60 psi, you can't beat Eastern VW series vane pumps. These highly efficient units are designed around a cam-shaped pumping chamber assuring pulsation-free liquid flow. Vanes are held in positive contact with the pumping chamber at all times — and their positioning is independent of hydraulic pressure or centrifugal force. Composition carbon graphite bearings and vanes require no lubrication beyond that of the liquid being pumped.

All Eastern positive displacement pumps are close-coupled with motor or can be furnished less electric motor with belt stand for belt or coupling drive.

Don't make your points the hard way — play safe and write for Eastern's new Bulletin 220 on positive displacement pumps.

Other Eastern products:

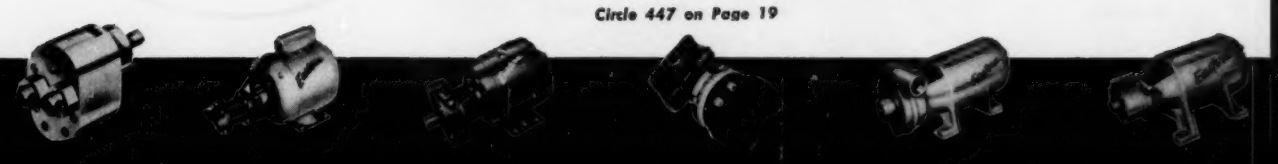
- *hydraulic motors*
- *gear pumps*
- *centrifugal pumps*
- *aircraft pumps*

EASTERN INDUSTRIES ★ PUMP DIVISION ®

EASTERN INDUSTRIES INCORPORATED

Hamden, Connecticut

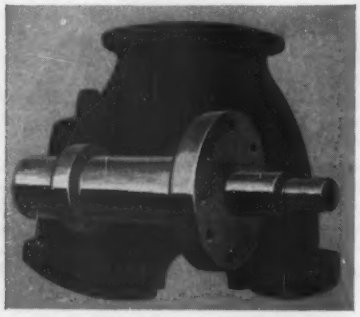
Circle 447 on Page 19



A simple, effective, low cost rust and corrosion control that . . .

- *is easy to apply*
- *eliminates moisture*
- *prevents corrosion*
- *need not be removed*

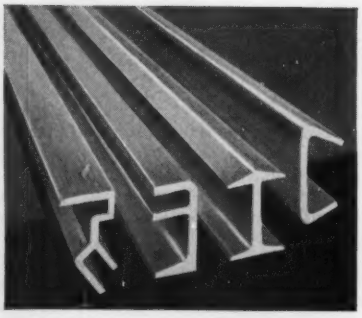
CRC 3-36 has a dual action which first removes moisture from the surface, driving it out of grain boundaries, cracks and pores. It then forms a thin molecular film of approximately 2 microns over the surface and seals it against subsequent deposits of moisture and the action of corrosive atmospheres.



For Castings & Large Machined Parts

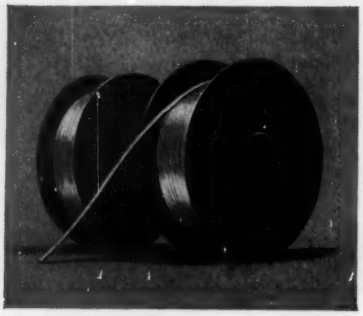
A steam turbine manufacturer, after exhaustive tests, now uses CRC 3-36 exclusively to protect metallic surfaces of parts and equipment in various stages of manufacture from deterioration due to corrosion. After standardizing on CRC 3-36, the necessity for stocking, coding and handling a wide variety of products was eliminated. In addition, CRC 3-36 does not have to be removed before subsequent processing. Substantial savings are being realized through the use of CRC 3-36.

This manufacturer has also found that CRC 3-36 will protect all metallic surfaces from rust and corrosion during shipment.



For Extruded Aluminum

An aluminum manufacturer received complaints that bright aluminum extrusions arrived at distribution points covered with a dull coating of oxide. Exhaustive tests under actual shipping conditions show that an inexpensive coating of CRC 3-36 eliminated oxidation during shipment and that distributors, in turn, could ship bright and shining extrusions months later to customers with no complaints about oxidation. Furthermore the extrusions were ready-to-use as CRC 3-36 does not have to be removed.



For Manufacturing Processes

The manufacture of welding wire poses a corrosion problem from coolants used to lubricate and cool dies used in the rolling or drawing process. One manufacturer of welding wire tried applying CRC 3-36 before running the stock through the mill and obtained excellent results. Now all stock is coated with CRC 3-36—corrosion is controlled and no stocks are lost due to rust.

New! CRC Soft-Seal for Severe Conditions

If you are using expensive interior storage space for metal stocks, dies, jigs and fixtures, these may be coated with Soft-Seal and stored outside to release inside space for productive use.

For further information, write to
Corrosion Reaction Consultants,
A SUBSIDIARY OF
THE CHAS. J. WEBB SONS CO., INC.
116-Y Chestnut Street, Phila. 6, Pa.,
or telephone WAlnut 5-0200.

CRC FORMULA 3·36 METALS INDUSTRY

Metal Protection for
MANUFACTURING • STORAGE • PACKAGING

Ask your local industrial distributor for a trial supply.

Circle 448 on Page 19

MACHINE DESIGN
March 2, 1961

Welcome Assurance

THE story is told of the young man who wanted to divorce his bride of a few weeks. "She won't do," he told the minister who had married them. "She can't stand correction."

Engineers don't like correction either—especially if it comes from outside groups good at hindsight and second-guessing. But a subjective, emotional reaction to any questioning or examining of their work is hardly a sign of professional maturity. Unfortunately, the attitude of some design engineers toward a reliability audit, as Dick Landers observes in his article overleaf, is occasionally one of complete rejection. Amateurs can't stand correction.

Equally unprofessional is complete dependence on such an audit. It suggests lack of confidence and too much eagerness to shed responsibility.

The auditing function, by that or any other name, is well accepted in other circles. Business people welcome the financial audit. Business magazines like MACHINE DESIGN use a circulation audit. In both instances the audit is proof—to stockholders or to advertisers—that a business or a publication has done what it said it would do under certain rules. In neither instance is the auditor expected to do the user's work for him.

In government the Supreme Court is a sort of auditor of laws passed by legislators—the rules here being the Constitution of the United States. But just as the Supreme Court refused to help F.D.R. predetermine the constitutionality of proposed laws, so the design engigineer should not expect the reliability auditor to help him do his work. The essence of effective auditing is detached, impartial judgment.

The complexity of today's equipment and systems puts a heavy burden of responsibility on the design engineer. The assurance of adequate backup should be welcome.

Colin Carmichael

EDITOR

WHAT are they?
Organized investigations and appraisals of products during all phases of conception, design, production, and usage.

WHY are they used?
To assure the customer of a given level of performance and endurance at the lowest possible cost.

HOW are they conducted?
By continuous, critical reviews to determine compliance with design and manufacturing standards.

WHERE are they applicable?
In medium to large-size companies. However, many of the ideas and principles discussed can also be applied in small companies.

Reliability

The ever-increasing complexity of products—both military and civilian—tends to increase the possibility that the product will not perform as intended.

Improved performance of purchased equipment is vitally important to the military services. They are beginning to require manufacturers to show evidence that positive steps are taken to assure compliance with agreed-upon standards and design criteria at all stages of design and manufacture.

This article details the procedure developed at Thompson Ramo Wooldridge Inc. to provide this positive control. However, the principles discussed are equally applicable to the design and manufacture of civilian consumer products.

Audits

RICHARD R. LANDERS
Chief
Tapco Group Reliability Office
Thompson Ramo Wooldridge Inc.
Cleveland, Ohio

JUST as the accounting audit provides management with an impartial, accurate picture of the company's financial position, the reliability audit gives a general, but accurate, summary of the engineering portion of the corporate structure.

Regular financial review is an accepted practice. In this review, actual performance is compared to budgetary estimates. Charts describing profit and loss are shown. Various yardsticks are presented to measure returns on investment, cash flow, and sales billed versus backlog. Thus, management has the information necessary to plan effective financial action.

However, the engineering phases of design and manufacturing are rarely reviewed in such documented detail. If the ratio of profit to net sales billed dropped by a fraction of 1 per cent, immediate action would be taken. On the other hand, the number of design changes in a given month may double or halve without the engineers being aware of the fact. A company may be heading toward engineering bankruptcy because of insufficient or inadequate engineering effort, but the harm can be done before management becomes fully aware of the seriousness of the situation.

Unfortunately, methods for evaluating engineer-

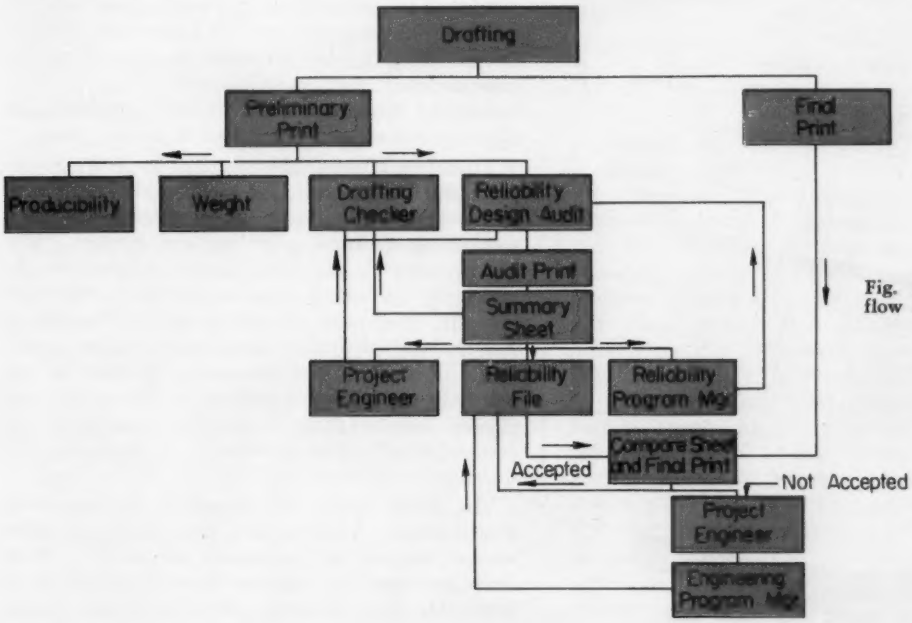


Fig. 1—Reliability audit flow chart.

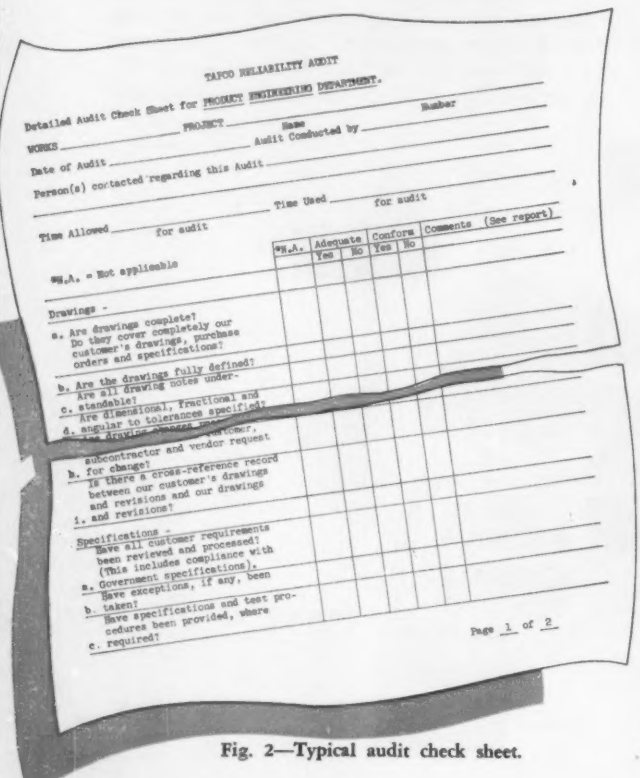
ing have not been developed as they have for finances. This article discusses an engineering-audit program which can supply the engineering yardstick.

In some cases, engineers may regard audits as an expression of distrust, or as a reflection on their ability. In practice, the audit can produce beneficial results regardless of whether the design or manufacturing process is good or bad. If the audit discloses weaknesses or errors, they will be caught early enough to be corrected at a minimum cost. Without the audit, these shortcomings would be revealed later under much less favorable circumstances. Furthermore, when errors or deficiencies are uncovered and corrections recommended, no one other than the auditor and the person involved need be informed. If no discrepancies are found, the audit verifies the engineer's competence.

Regardless of previous attitudes, once the audits are started, all fears and doubts usually disappear. The auditors should take the "confidential rule" very seriously. Supervisors should not be permitted to see audit working sheets. However, a representative sample should be made to show the type of discrepancies disclosed. Copies of the summary sheet indicating the auditor's recommendations and the engineer's response to these suggestions should be distributed to the supervisors.

Reliability Audit vs. Design Review

At first glance it may appear that reliability auditing is simply a new name for the already existing practice of design reviews. Although there are many similarities in method, there are also several important differences. Design reviews are scheduled at key stages of development—usually after the design is completed, sometimes not until the prototype is available. But engineering audits are performed continuously as the design develops. Design reviews are attended by several specialists not directly associated with the design, while reliability audits are conducted by one or two engineers closely associated with the project.



TAFCO RELIABILITY AUDIT

Detailed Audit Check Sheet for PRODUCT ENGINEERING DEPARTMENT.

WORKS _____ PROJECT _____ Name _____ Number _____

Date of Audit _____ Audit Conducted by _____

Person(s) contacted regarding this Audit _____

Time Allowed _____ for audit _____ Time Used _____ for audit

N.A. = Not applicable

	N.A.	Adequate Yes	Adequate No	Conform Yes	Conform No	Comments (See report)
Drawings -						
a. Are drawings complete? Do they cover completely our customer's drawings, purchase orders and specifications?						
b. Are the drawings fully defined? Are all drawing notes understandable?						
c. Are dimensional, fractional and angular tolerances specified?						
d. Are drawing changes [illegible] subcontractor and vendor request for change?						
e. Is there a cross-reference record between our customer's drawings and revisions and our drawings and revisions?						
Specifications -						
a. Have all customer requirements been reviewed and processed? (This includes compliance with Government specifications).						
b. Have exceptions, if any, been taken?						
c. Have specifications and test procedures been provided, where required?						

Page 1 of 2

Fig. 2—Typical audit check sheet.

Designers may feel that an audit is an unnecessary duplication of effort. After the function and purpose of reliability audits have been explained, there may still be a hostile reaction to any change in the status quo. This reaction is intensified if the persons concerned are not fully aware of the purpose or methods of the audit. However, when the auditor is accepted as a member of the design team, the professional integrity of the designer is maintained and the auditor is no longer considered as an outsider "looking over the engineer's shoulder."

The engineer must understand that the auditor views the project from angles not necessarily considered by design engineers. The auditor makes a positive contribution toward the completeness of the program, rather than a negative criticism of the work of the design engineers. The auditor is the shortstop on the ball team who plays between the bases, covering ground which is slightly beyond the reach of his teammates.

There are several similarities between design reviews and reliability audits. The broad objective, the assurance of obtaining the best product possible, is the same. The question naturally arises, "Are reliability audits and design reviews complementary, or do they represent different stages of the same function?"

In the past, when management wanted an appraisal of design effectiveness, a group of experts was asked to review the design and suggest improvements. Many suggestions were timely and effective. Often, however, design-review procedures became more or less formalized. Chairmen, recording secretaries, and permanent members were appointed and the time was scheduled in terms of project phases.

There are inherent shortcomings in design-review practice. For example, the members of the design-review group often have other assignments which prevent them from attending the rievews. Frequently they do not have time to prepare for the review by evaluating the design prior to the meeting. In these cases, the design review degenerates to a meeting for product orientation and familiarization. In concluding the meeting, the chairman can ask only such broad questions as "Have you considered maintainability?" or "Did you design for producibility?" The answers are as general as the questions—variations of "Yes, we did."

The design audit was devised to overcome these shortcomings. Auditors are not borrowed when needed, but are on permanent assignment. Audit techniques are not centered around general questions. Instead, they include a systematic proce-

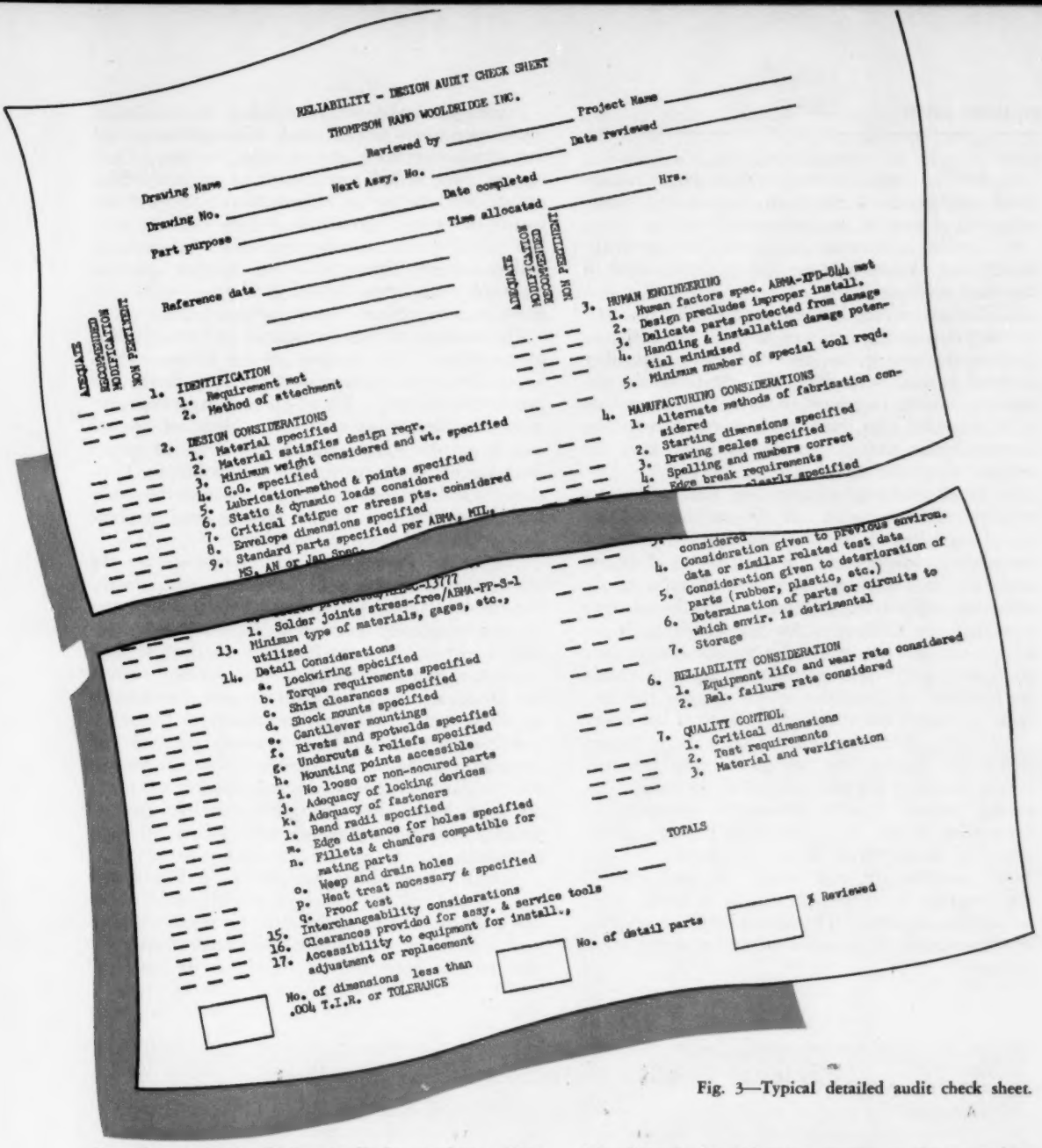

RELIABILITY - DESIGN AUDIT CHECK SHEET
THOMPSON RAMO WOOLDRIDGE INC.
Project Name
Reviewed by
Date reviewed
Drawing Name
Next Assy. No.
Drawing No.
Date completed
Part purpose
Time allocated
Hrs.
Reference data
ADEQUATE
RECOMMENDED MODIFICATION
NON PERTINENT
1. IDENTIFICATION
1. Requirement met
2. Method of attachment
2. DESIGN CONSIDERATIONS
1. Material specified
2. Material satisfies design reqr.
3. Minimum weight considered and wt. specified
4. G.O. specified
5. Lubrication-method & points specified
6. Static & dynamic loads considered
7. Critical fatigue or stress pts. considered
8. Envelope dimensions specified
9. Standard parts specified per AFMA, MIL, NS, AN or Jan Spec.
3. HUMAN ENGINEERING
1. Human factors spec. AFMA-XPD-044 met
2. Design precludes improper install.
3. Delicate parts protected from damage
4. Handling & installation damage potential minimized
5. Minimum number of special tool reqd.
4. MANUFACTURING CONSIDERATIONS
1. Alternate methods of fabrication considered
2. Starting dimensions specified
3. Drawing scales specified
4. Spelling and numbers correct
5. Edge break requirements clearly specified
1. Solder joints stress-free/AFMA-PP-S-1
13. Minimum type of materials, gages, etc., utilized
14. Detail Considerations
a. Lockwiring specified
b. Torque requirements specified
c. Shim clearances specified
d. Shock mounts specified
e. Cantilever mountings
f. Rivets and spotwelds specified
g. Undercuts & reliefs specified
h. Mounting points accessible
i. No loose or non-secured parts
j. Adequacy of locking devices
k. Adequacy of fasteners
l. Bend radii specified
m. Edge distance for holes specified
n. Fillets & chamfers compatible for mating parts
o. Weep and drain holes
p. Heat treat necessary & specified
q. Proof test
15. Interchangeability considerations
16. Clearances provided for assy. & service tools
17. Accessibility to equipment for install., adjustment or replacement
considered
4. Consideration given to previous environ. data or similar related test data
5. Consideration given to deterioration of parts (rubber, plastic, etc.)
6. Determination of parts or circuits to which envir. is detrimental
7. Storage
6. RELIABILITY CONSIDERATION
1. Equipment life and wear rate considered
2. Rel. failure rate considered
7. QUALITY CONTROL
1. Critical dimensions
2. Test requirements
3. Material and verification
TOTALS
No. of dimensions less than .004 T.I.R. or TOLERANCE
No. of detail parts
% Reviewed

Fig. 3—Typical detailed audit check sheet.

dure for covering all facets of the product. Furthermore, audit methods facilitate absorbing new and effective standards and ideas into a project, as well as simplifying the transfer of information from one project to another. Improvements and suggestions are fully documented for ready reference. A mistake need not be repeated, nor the wheel reinvented each time it is needed.

Functions and activities of all departments should be included in a general company audit. However, since plans and procedures for the engineering and manufacturing components are generally the most important, they will be described in greater detail.

Audit Methods

During specific design stages, for example when layouts are completed and drawings are ready to be released, the following events, as shown in Fig. 1, occur in order:

1. The chief auditor receives a copy of the preliminary blueprints as they are finished each day.

2. The chief auditor logs them in and checks them for importance and complexity. Standard drawings require only spot checking.

3. Time allocated for auditing each drawing is marked on the audit work sheet. Generally this time ranges from 2 hr for detail drawings to 20 hr for major assemblies. Even though many drawings may be ready each day, they must be released by the auditor within 24 hr. In this case, only a preliminary audit can be made. Occasionally not all drawings can be audited at this time. In this situation, the drawings are given a priority designation. As time permits, they are analyzed in more detail.

4. The chief auditor assigns the drawings, supporting material, and forms to assistant auditors.

5. Assistant auditors work within the time allocated and indicate on the audit check sheet the percentage and part of the audit completed.

6. Drawings, drawing-change requests, summary sheets, and recommendation sheets are returned to the chief auditor.

7. Copies of the recommendation sheets and drawing-change requests are sent to the designer, drafting checking group, and draftsman. All other material is filed with the print. At times the designer is unable to review recommendations within a 24-hr period. In these cases, the draftsman can discuss design change recommendations with the designer at a later time.

8. Final drawing releases are compared later with the filed material. If the recommendations have been followed, the final drawing is substituted for a preliminary print. If not, the auditor returns to the design engineer and attempts to resolve the differences personally. In the extreme case that the differences are not satisfactorily resolved, the problem would be brought to the program manager. The reliability supervisor should be informed of problems which require the program manager's attention—the method of last resort.

All audit efforts are recorded on working papers, which are divided into two parts. The first portion is the check list which serves as an index. The second portion contains schematics, designs, and summaries of test data. Working papers are also compiled during later stages of product development, manufacture, and usage. As each item in the program is completed, a note is made of the actual time required. This record helps assure proper apportioning of time allowances in planning future audits.

During the audit, pertinent failure data and field reports are reviewed and listed. The auditor should not accept everything at face value, but should test various design and manufacturing criteria. This testing may require an independent analysis of the specifications to compare the results with the original calculations, the weighing of several parts to assure correspondence with the weights specified on the drawing, recalculation of tolerance accumulations, or reinspection of manufactured parts.

The working papers give extent and proof of the examination. They include all the evidence gathered, the work accomplished, and methods and procedures followed. These working papers are permanently filed, thus serving as historical records and as aids for subsequent audits. Working papers must be complete, organized, and in sequence. Conclusions and recommendations attached to the working papers ensure a design review based on field data when they become available.

"Organized investigation and appraisal" are the characteristics of the audit procedure which make the reliability specialist accepted by the design and the manufacturing engineers. The reliability auditor does not point his finger at the designer and warn him to make the equipment reliable, or face the consequences. The auditor's prime purpose is to advise and counsel, not to criticize or police.

Although work should be properly planned and documented, the audit procedure must not become too standard. There is danger in relying too much on prior work. Even though check lists are frequently used, no ready-made form will fit all audit situations.

Sample check sheets are shown in Fig. 2 and 3. Extent of the tests and procedures to which the audit is to be restricted must be clearly outlined and understood. Should a controversy arise, the auditor can insist that the designer or industrial

Personal Qualifications: Reliability Auditor

A reliability auditor is not a specialist. He is a counterbalancing generalist in a growing army of specialists. It is the specialization, made necessary by technological progress, that has produced the need for reliability auditors.

As each speciality becomes more concentrated, a gap is produced between specialists that must be bridged to achieve a unified approach. The reliability engineer is in a good position to bridge this gap. He is unbiased, his sources of data are unlimited, he knows the expectations of the customer, and he is familiar with past, present, and future engineering capabilities. From this information, he can make a fair, over-all appraisal of the current status of the project.

The reliability auditor must have adequate technical training and proficiency. His experience and ability should at least equal, and preferably exceed, the average. Once assigned, the auditor requires no authority beyond that commanded by his ability and experience. His integrity should be such that other members of the organization can place full confidence in his work. He should not offer advice on the subject in which he does not have advanced knowledge. However, auditors should be selected so that all fields are covered.

He should maintain an independent mental attitude in all matters relating to the assignment.

He should exercise proper professional care in performing the examination and preparing the report. Factual data must be meticulously correct. Reports must be brief, significant, constructive, and easily understandable.

He should make recommendations that are workable and that reflect good design principles. Even though a good theoretical background is essential, the work of the engineering auditor should be primarily practical in nature.

The auditor must be diplomatic in his activities. Reporting should be unbiased and in no way discredit or ridicule. The auditor does not try to find fault or affix blame for honest mistakes. One of his purposes is to introduce a fresh and unbiased viewpoint into the project organization.

engineer produce data supporting the selection of a particular design or process. This procedure avoids clashes based solely on opinion. In any event, sufficient data must be obtained through inspection, observation, inquiries, and personal contact to afford a reasonable basis for an opinion regarding the subject under examination.

Audits should not be conducted by remote control. They should take place as close to the work being audited as is physically practical. An unhurried, friendly atmosphere yields the best results.

The auditor should perform his function early enough in a particular program so that corrective action, if necessary, can be accomplished without delaying the project. This timing also prevents second guessing obvious errors or discrepancies.

The auditor looks for specific items. Any errors disclosed must be handled carefully to avoid personal embarrassment.

Specific recommendations should be the only output of the audit generally seen by others. Whenever possible, these recommendations should be requests for drafting or manufacturing specification changes and should require only the signature of the engineer to indicate concurrence.

No drawing, specification, or planning-document release should be delayed more than one day by the auditors. Furthermore, no one should feel that the auditor's approval is necessary before work can be completed. If this practice becomes prevalent, the auditor becomes a bottleneck.

Audit plan, results, and recommendations are permanently filed by drawing or specification release number for reference or re-examination in the future.

Summary Statement

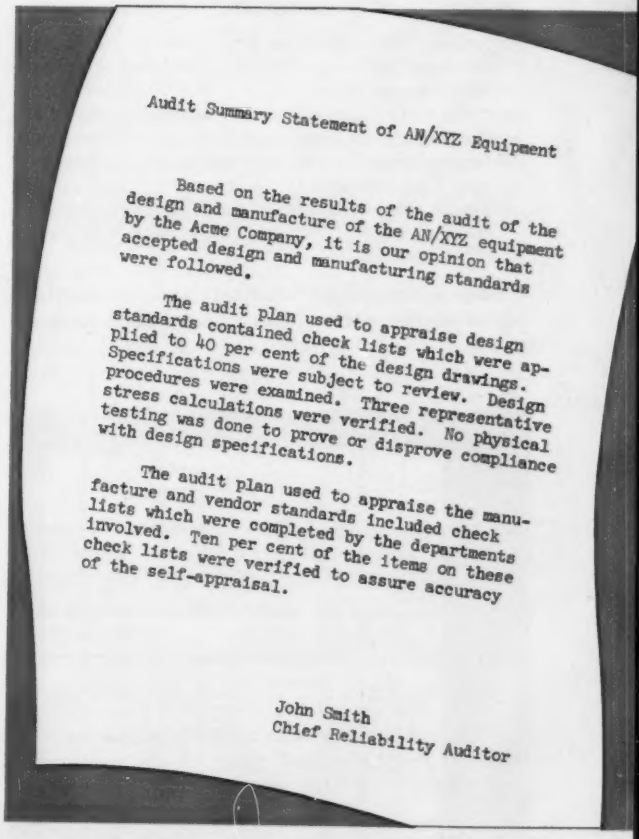
After the audit is completed and the report prepared, an audit summary statement, Fig. 4, is prepared as a preface to the report. This statement, signed by the chief reliability auditor, gives the degree of compliance with acceptable standards as disclosed by the audit. It also lists the material included and the assurance techniques used in making the judgment. In preparing his statement, the auditor should be very careful in his choice of words, especially those involving "checking." In practice, the word checking is avoided because its meaning has become vague from over-use. In its place, more precise and descriptive terms such as compare, reconcile, or examine should be used for greater effectiveness. A list of suggested terms is shown in the Glossary.

Note that the only thing "vouched for" was whether or not acceptable standards were followed. The audit does not attempt to predict the customer's satisfaction with the results, or whether design and manufacture will meet the customer's specifications and requirements. Such a prediction would be comparable to an accounting auditor not only certifying that the books balance, but also that business will be good and the stockholders overjoyed. Although the auditor is in the best position to evaluate the project, to maintain his objective attitude, his sole task must be to determine the degree of compliance with pre-established standards.

Standards, because of their importance, deserve special mention. In many cases, standards consist merely of understandings developed over the years, each essentially the result of specific problems that have occurred through the years. The resulting negative philosophy is "If it cannot be

Glossary

Compare: To observe similarity or variation in particular items from one period to the next.
Evaluate: To determine capability over a range of applications.
Examine: To carefully inspect or review a record or design.
Qualify: To determine capability in a given application.
Reconcile: To establish agreement between two sets of data which are similar but have been arrived at independently.
Test Checking: To select and examine a representative sample from a large number of similar items.
Trace: To follow data from one record to another to insure its inclusion and continuity.
Verify: To establish the validity and accuracy of data by rechecking actual tests or occurrences.
Vouch: To attest to the accuracy of design and test data.



Audit Summary Statement of AN/XYZ Equipment

Based on the results of the audit of the design and manufacture of the AN/XYZ equipment by the Acme Company, it is our opinion that accepted design and manufacturing standards were followed.

The audit plan used to appraise design standards contained check lists which were applied to 40 per cent of the design drawings. Specifications were subject to review. Design procedures were examined. Three representative stress calculations were verified. No physical testing was done to prove or disprove compliance with design specifications.

The audit plan used to appraise the manufacture and vendor standards included check lists which were completed by the departments involved. Ten per cent of the items on these check lists were verified to assure accuracy of the self-appraisal.

John Smith
Chief Reliability Auditor

Fig. 4—Sample audit summary statement. If some engineering or manufacturing standards were not acceptable, the statement would be modified to read . . . "that while, in general, acceptable design and manufacturing standards were adhered to, the following practices were examined and failed to conform to acceptable standards."

proved harmful, then assume that it is good."

Fortunately, it is not too late. Since reliability auditing is still in the formative stages, a set of standards can be adopted which specifically defines what is desired and necessary. The current tendency is to take corrective action only on things that have already proved undesirable. Established standards will permit preventive action to avoid undesirable consequences.

Reaction to Audits

When the audit plan was introduced at Thompson Ramo Wooldridge Inc., the necessity for engineering and manufacturing audits was questioned. Engineering audits had never been performed previously in the company. They are not generally conducted in industry although they have been conducted by the military (e.g. MIL-Q-9858), but only at widely spaced intervals.

After the plan was in operation the most unfavorable comment made was in regard to preliminary drawings. It was felt that the auditor duplicated the work of the drafting checker. To some extent, this is true. In reply, however, the following items must be recognized:

1. Auditing of preliminary prints is done at the request of project leaders to minimize the number of formal design-change requests.
2. Auditors have over-all project information that the checkers may not have.
3. Separate reliability funds are used, so that no development funds are diverted.
4. Finally the very nature of audit procedures requires the duplication of previous work to verify and check current practices and efforts.

Some management personnel expressed their approval of the audits by describing them as a reliability tool that yields beneficial results which are apparent immediately. The audit procedure also provides management a yardstick by which the individual output of reliability engineers can be measured. The output of the auditor can be compared to the input, that is, the number of audits handled, percentage of individual audits completed, and the effectiveness of recommendations.

Another apparent benefit is the demonstration of ability independent of personal charm and persuasiveness. Shortly after the inauguration of the audit procedure, the talkers were separated from the doers. Although diplomacy and tact are prerequisites, recommendations made as part of the audit plan are adopted only by virtue of their validity, timeliness, and completeness. Verbal selling is replaced by written communication. As may be expected, some of the best auditors are these capable engineers who had been overshadowed previously by their more verbose associates.

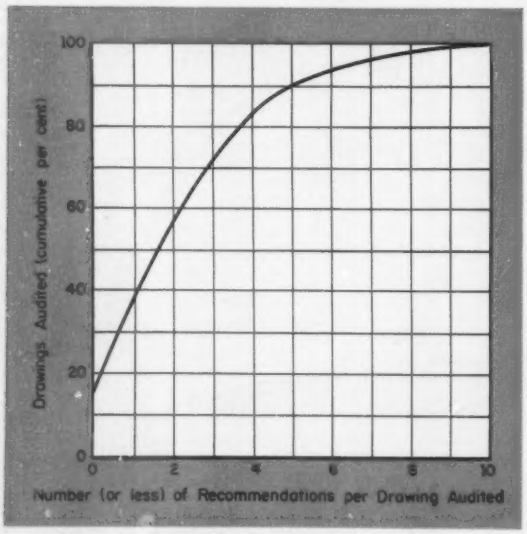


Fig. 5—Recommendations versus drawings audited.

Results of First Audit

Deficiencies in the initial audit are to be expected. These result from applying a new system while concurrently working out difficulties in the existing system. With experience, effective methods can be more readily developed for each audit situation.

Hidden deficiencies in the design system will detract from the effectiveness of the audit. The design audit is basically aimed at determining compliance to accepted design standards. If these standards are inadequate, the effort ordinarily spent in conducting the audit should be applied to improving these standards.

The audit recommendations often include a preponderance of minor items, such as misspelled words on drawings. If these details are in error, they should not go unreported. However, experience has shown that it is better to concentrate on fewer drawings and check them more thoroughly. Eighty per cent coverage (that is, examination of eight of every ten items on a drawing), for 40 per cent of the drawings is a good target.

Should every discrepancy be recorded in the audit, the following results can be expected in an audit of 1000 drawings: 1. An average of one discrepancy per drawing for a total of 1000 discrepancies. 2. Only 25 of these 1000 have serious consequences. 3. Another 25 serious discrepancies on the drawings which were examined have been overlooked.

Therefore, subsequent audits of similar equipment should be directed toward discovering the 50 serious shortcomings for every 1000 drawings. With experience, it will be possible to decide which drawings should be examined in detail and which should only receive a casual check.

Since design engineers are usually assigned to an assembly or unit in the design system, the parts of the product dealing with the joining of major assemblies or units are generally neglected. The reliability auditor can most profitably concentrate on this area. Additionally, the design engineer, by re-

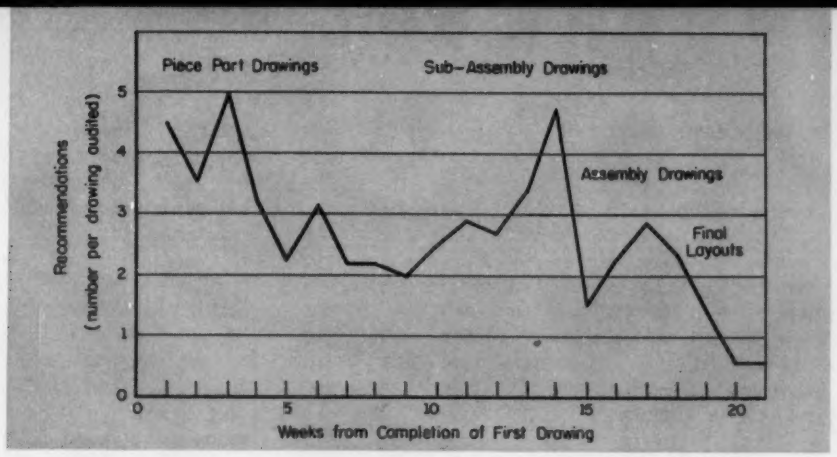


Fig. 6 — Variation in number of recommendations during the course of a design project.

viewing his own working area, can generally find as many deficiencies as the auditor.

The attitude of the design engineer toward the auditor may range anywhere from complete rejection to complete dependence. The auditor must strive to create a receptive attitude among the engineers with whom he works. Full co-operation can frequently be obtained by pointing out that the competent engineer should have nothing to hide in his design. In general, a professional attitude prevails once the novelty of the audit situation has worn off.

The major benefits from an audit become apparent at the assembly and test of the first completed product. If the audit was properly conducted, there should be no excessive schedule delays and no major deficiencies requiring extensive redesign.

The reliability audit effort itself should be evaluated. The question that may be asked is, "For the amount of time and money spent, did a comparable gain result?" Every discrepancy of reasonably serious proportion revealed and corrected in the initial design stage represents an average saving of four engineering man hours, two drafting man hours, and a delay in production of eight hours. Therefore, the break-even point for the cost of conducting an audit is the number of serious discrepancies uncovered multiplied by the cost of each design change and resultant schedule delay.

Fig. 5 and 6 show the trend of the number of recommendations made in a typical audit. As shown in Fig. 5, 72 per cent of the drawings required three or fewer changes. As shown in Fig. 6, the trend of recommendations per drawing peaks at three distinct times during the design program.

On the average, 90 per cent of the design changes recommended by the audit are accepted and immediately incorporated in the design. Usually, eight per cent are either unnecessary or improperly made. One per cent of the recommendations subsequently become meaningless due to other design changes. The remaining one per cent, assuming they were proper and necessary, should be disclosed during qualification and acceptance tests, or become apparent in actual usage. The ratio of discrepancies revealed in test to those uncovered in actual usage is ten to one. However, the losses resulting from this last 0.1 per cent of the change recommendations that were ignored often justifies doubling the audit effort.

The cost savings depend upon the program phase in which the corrective changes are made. As a rule of thumb, it costs one higher order of magnitude to correct a given discrepancy in each successive program phase. For example, if it cost one dollar to correct a deficiency in the preliminary or mark-up drawing stage, it will cost ten dollars in the final-drawing stage, when a drafting change notice is required, one hundred dollars in the release drawing stage for a production change notice, one thousand dollars in the production stage to rework or scrap, and ten thousand dollars for retrofit kits or modification of equipment in use.

Provisions should be made for covering the phase after the formal design drawing audit has been completed but before failure analyses are available on production parts. Items which should be considered are clearances, assembly fits, human-factor considerations, maintenance, and operational factors. The auditor is in the best position to perform this activity because he is familiar with the design specification requirements, as well as the problems which had been postponed until assembled production parts were available.

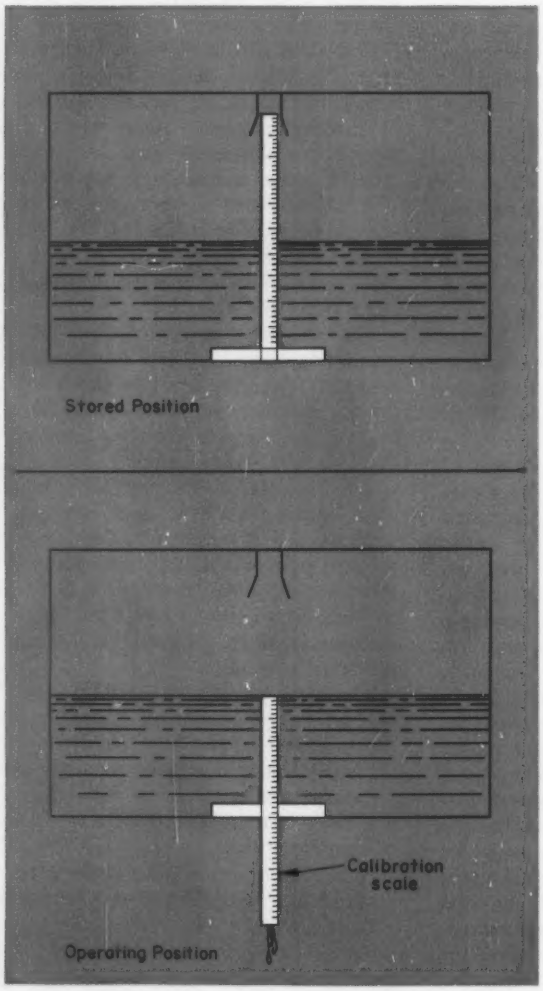
The auditor reviews a design, makes his recommendations, and then goes on to another area of the design. When he has completed all areas of the design program, he then starts the circuit again, making his round in the same manner, but not necessarily in the same order.

This method has many advantages: The auditor accomplishes a more complete and even coverage. The designer does not spend time preparing for the audit. The auditor does not become bogged down on a specific problem. Most important, each designer has a fair chance to consider recommendations disclosed by the audit in an unpressured manner.

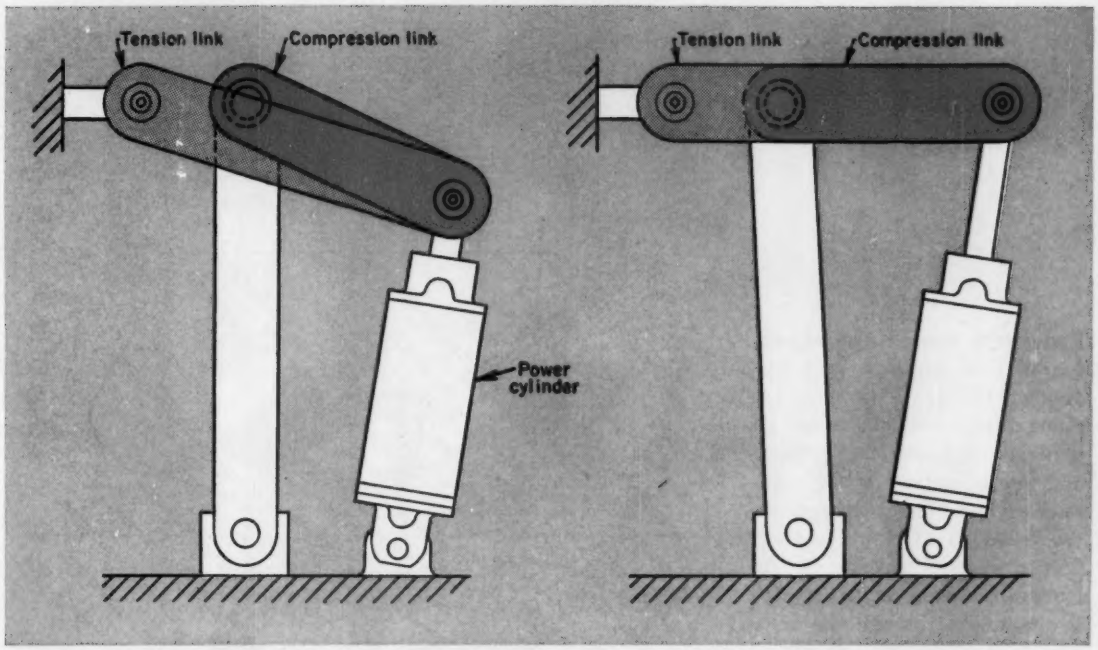
The audit procedures should not be changed once the program has started, even though corrections are indicated. Otherwise more time will be spent on improving or modifying the audit procedure than in applying it. In many instances, these changes are minor or would apply only in specialized or unique situations.

A review or critique at some later stage in the program is appropriate to properly evaluate the results of the audit. In many cases, frank and honest opinions can serve as a basis for improving audit techniques for future programs.

scanning the field for *ideas*

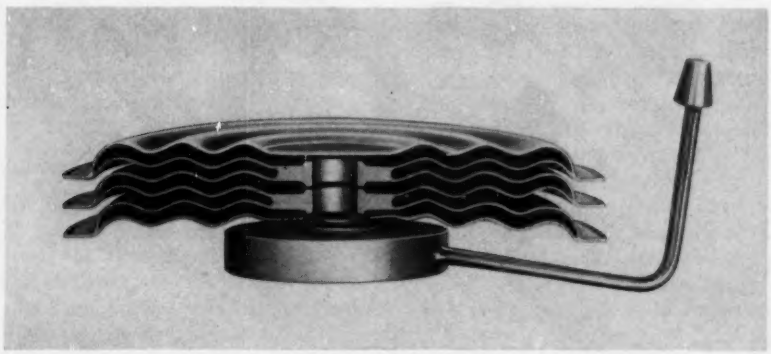


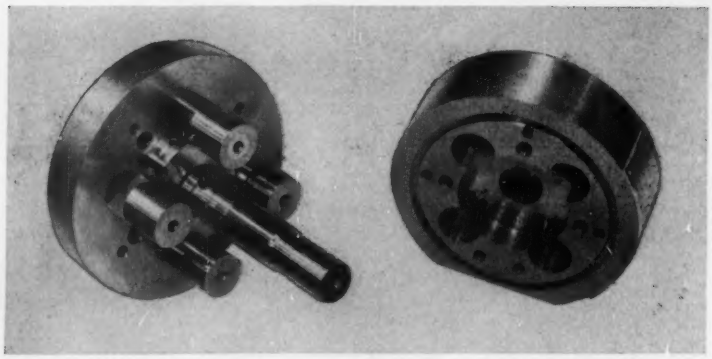
Drip stick measures liquid level from bottom of tank. To measure the liquid level, the hollow tube is withdrawn from the tank until liquid drips from the lower end of the tube. Liquid level is then determined by reading the tube calibration against the inside edge of the mounting flange. Principle employed in fuel quantity gage for aircraft. Gage manufactured by Accessory Products Co., Whittier, Calif.

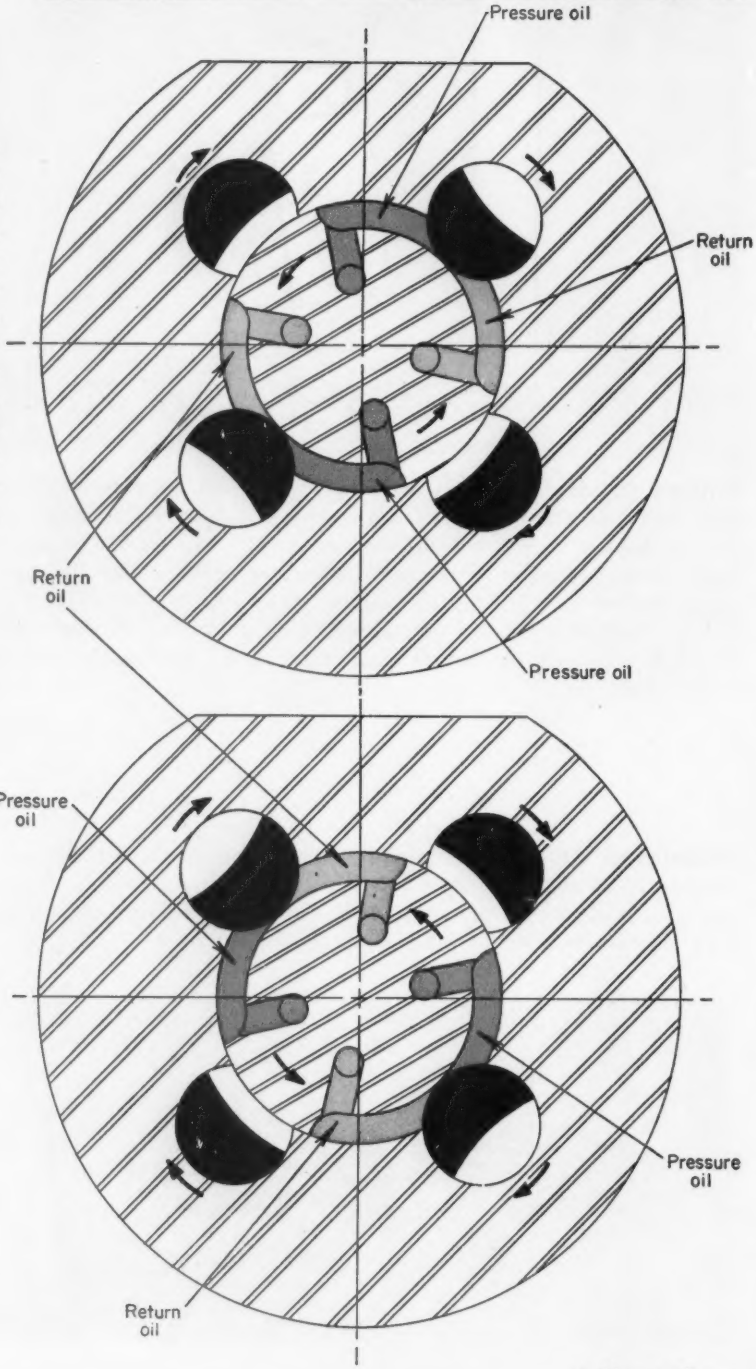


Folded toggle linkage combines tension and compression links to reduce effect of temperature variation upon force output. In the usual toggle-link mechanism, in which both members are in either tension or compression, thermal expansion or contraction effects are additive. Thus, for a given input, output varies with temperature. However, in this folded toggle linkage, thermal expansion or contraction tends to be self-compensating. Principle employed in thread-rolling machine by Landis Machine Co., Waynesboro, Pa.

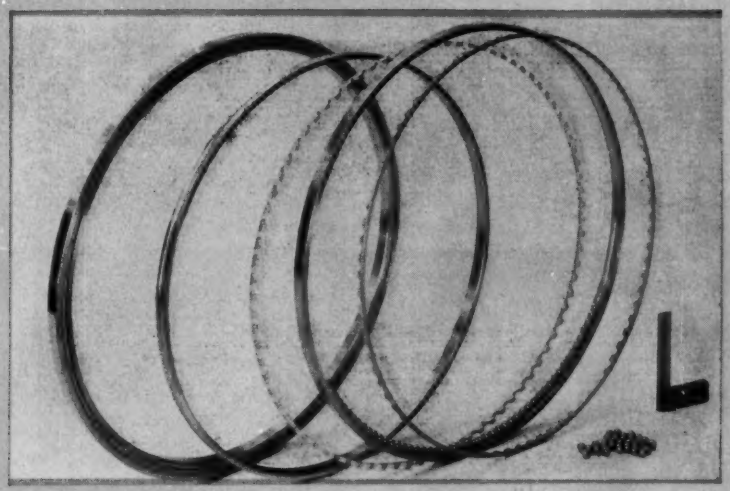
Undulated diaphragm plates permit nesting to reduce over-all height without reducing output travel of pressure-sensing capsule. Principle employed in element of pressure gage by United States Gauge Div. of American Machine and Metals Inc., Sellersville, Pa.







Rotating reaction vanes control flow sequence in a hydraulic motor. Timing gears rotate the flatted-shaft vanes so that they separate the pressure and return portions of the main rotor cavities. The reaction vanes are timed so that the cutaway portion permits passage of the lobes of the main rotor. Oil flow is continuous through the pressure and return passages. Principle employed in a hydraulic motor developed by Hartmann Mfg. Co., Racine, Wis.



Thin-Race Bearings

- *Types*
- *Characteristics*
- *Performance*
- *Applications*

H. ALAN DUGUID
Huntington Industries
Shelton, Conn.

THERE is no sharp dividing line between thin-race bearings and standard bearings. All thin-race types have their counterparts in the standard series. Size alone is not a criterion; thin-race bearings have been produced in bores from 2 to 150 in.—the same as standard bearings.

The best distinction between the two types is the relationship of bearing bore to bearing-section height, the section height being one-half the difference between the bore diameter and the outside diameter of the bearing.

In standard bearings, the ratio of bore to section height usually ranges from 3.5 to 1 for the extra-light series, to 1.8 to 1 for the medium series. For heavy-duty bearings, these ratios may be even smaller. Fig. 1 gives a representative comparison.

In contrast, thin-race bearings are available from several sources in bores from 2 to 12 in., with sections as small as 0.25 x 0.25 in giving a bore to section-height ratio as high as 48 to 1. These bearings are also available in sections up to 1 x 1 in., and in bearings of larger bore they are available in section sizes above 1 in. In all cases thin-race bearings are characterized by a large bore-to-section-height ratio. As an example, a standard ball bearing of the extra-light series is of the following size:

THIN-RACE BEARINGS

12.5984 x 19.6850 x 2.7953 in. In a thin-race bearing for bores of 12.500 in., bearings are available in the following sizes:

OD	Width	OD	Width
13.000	0.250	13.500	0.500
13.125	0.312	14.000	0.750
13.250	0.375	14.500	1.000

In addition to these, intermediate sizes as well as larger section sizes can be obtained.

Bearing Types

There are six major types of thin-race bearings

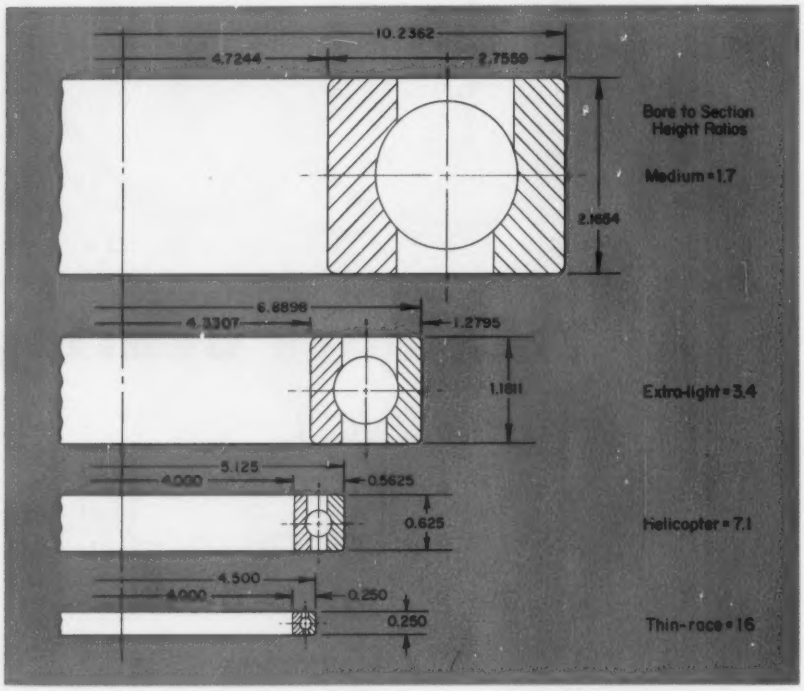


Fig. 1—Dimensional comparison of four types of angular-contact bearings in the same bore range, with comparative bore to section-height ratios.

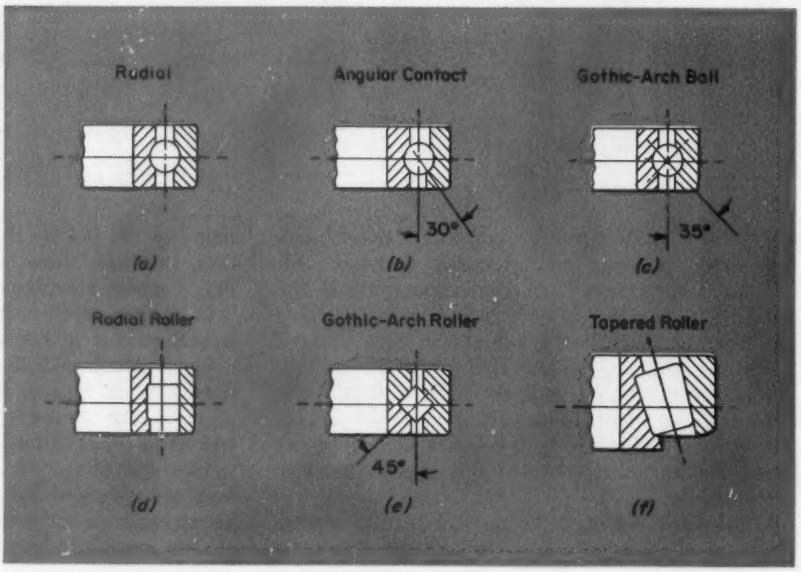


Fig. 2—Six principal configurations of thin race bearings. Bearings in *a*, *b*, and *c* are available in 0.25 x 0.25 sections and larger, with bores starting at 2 in. and available, in heavier sections, to 150 in. Bearings in *d* and *e* are available in 0.50 x 0.50 sections and larger, with bores also from 2 to 150 in. Smallest section size available in *f* is 0.812 x 0.750, with bores from 4 to 30 in.

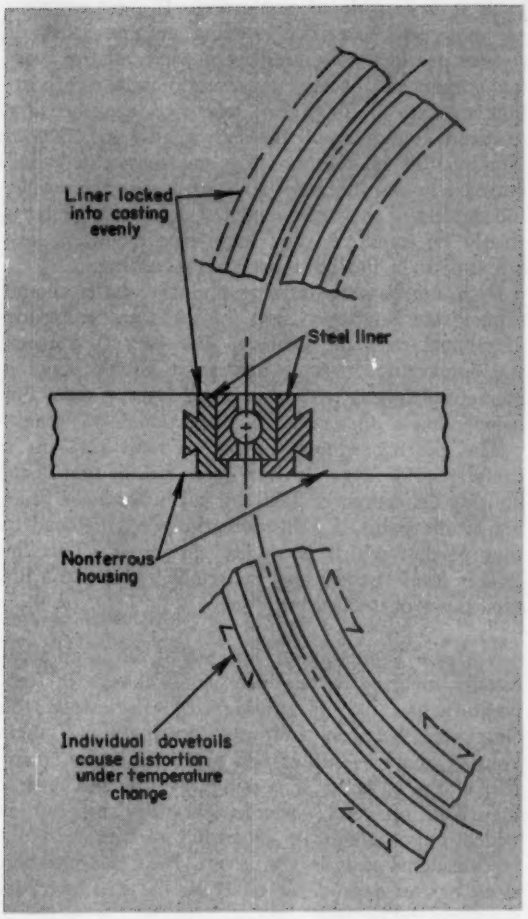

Liner locked into casting evenly
Steel liner
Nonferrous housing
Individual dovetails cause distortion under temperature change

Fig. 3—Dissimilar-metal bearing installation, showing one method of locking a steel liner into a casting. Individual dovetails should be avoided since they can cause distortion of the housing during temperature changes.

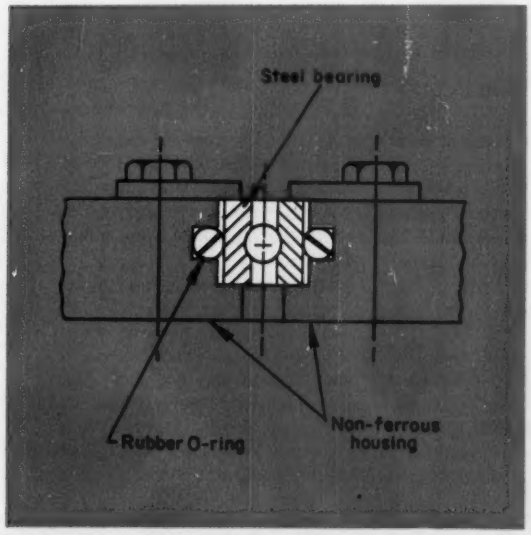


Fig. 4—Rubber O-rings are installed in grooves machined in a nonferrous housing, and compensate for thermal expansion of the housing and bearing. This type of installation is suitable only for small bearings under light load.

available, Fig. 2:

1. Radial ball.
2. Angular contact.
3. Gothic-arch ball.*
4. Radial roller.
5. Gothic-arch roller.*
6. Tapered roller.

In general, radial ball, angular contact, radial roller and tapered roller bearings in thin-race versions are used in much the same way as standard types.

Gothic-arch ball bearings and Gothic-arch roller bearings are not generally well known. They are extremely useful, however, since they can absorb not only radial loads, but also thrust in both axial directions. Thus, they can support a rotating device without the need for a second bearing.

When Gothic-arch bearings are used with their centerline of rotation vertical, they are mainly used singly. But in horizontal applications where overhung loads are large, the structure outside the bearing may deflect. To overcome this deflection, an outboard bearing is generally used. In this case, the outboard bearing should be of the radial type, with a considerable amount of axial float. Because a Gothic-arch bearing has thrust capacity in both directions, and thus tends to position the rotating member, any thrust capacity in the outboard bearing may cause the bearings to work against each other, resulting in premature failure.

Most thin-race bearings are produced from 52100 alloy steel, although they have been made in 300 and 400 series stainless steel and other materials.

Design Characteristics

Since one of the prime reasons for the use of thin-race bearings is to save weight, some applications require that either the housing or shaft, or both, be made of aluminum or magnesium. So housing and shaft rigidity can become a problem.

Because of the large ratio between their bore and section size, thin-race bearings are very flexible. This is due mainly to the low radial moment of inertia. As a result, these bearings are not round, even though the bearing races were round after the final grinding operation. Thus, housing bores and shafts must be held round to very close limits. Regardless of the shape of the bearing, it will conform to the shape of the housing and shaft because of its inherent flexibility.

Bearing Components: Although the balls and rollers used in thin-race bearings are held to very close limits, there is nevertheless some variation in size. This variation causes the rolling elements to travel at different rates of speed. Although this is undesirable in any bearing, it can become critical in thin-race bearings. For this reason, bearings without a retainer should not be used in any application where the rolling elements are under steady load. They can, however, be used when only oscillation is present.

*Gothic-arch ball bearings are also known as four-point contact ball bearings; Gothic-arch roller bearings, as X-type roller bearings.

THIN-RACE BEARINGS

Waviness of the ball path and wobble of the balls can result in erratic bearing operation by causing the speed of the balls to vary. In most applications, however, this condition will have little effect on bearing operation. In any event, this is primarily the bearing manufacturer's responsibility. For bearing seats, finishes of 8 to 12 mu in. are usually specified. Even with this finish, care must be taken that no chatter occurs in machining, since the resulting ripple in the housing surface is transmitted to the balls as they travel around the races. It has been found that a ripple or waviness in the housing bore surface of as little as 0.0005 in. may cause bearing malfunction.

Bearing Supports: To assure reasonable life, thin-race bearings should be installed so that there is uniform loading of the rolling elements. In a thrust application, each rolling element should carry an equivalent amount of load, while in a radial application as many rolling elements as possible should carry the load.

Thin-race bearings are flexible and incapable of bridging any discontinuity in the supporting structure. So the housing and shaft, in addition to maintaining bearing roundness, must also provide sufficient support so that the bearing can transmit the loads it is capable of supporting. If rigid supports are not used, localized loading results, localized stresses are increased, and the capacity of the bearing is reduced. Because the races of thin-race bearings are very flexible, close tolerances are necessary to insure roundness of the bearing after installation. Nominal fits in both housing and shaft should fall between line-to-line and 0.001 in. loose. If possible, the rigidity of the inner-race and outer-race supports should be equal. A rigid inner-race mounting will not support a flexible outer-race mounting.

Both the bearing housing and the shafts should support the bearing so that the loads are uniformly distributed over the bearing. For very thin races, the supporting housing and shaft should have a moment of inertia twice that of the bearing race. For heavier races this ratio is proportionately greater.

The bearing supports must be rigid through a complete 360 deg. It has been found that local housing deflections of 0.001 in. will unload the bearing at the point of deflection, throwing the load to that portion which is rigidly supported. This increases local stresses and materially reduces the life expectancy of the bearing.

Variable Temperature: Because of the large bores usually involved, a relatively small change in temperature can have a considerable effect upon the clearances between thin-race bearings and their housing and/or shaft, as well as on the actual operation of the bearing. If bearings with a bore greater than 4 in. are used, variable operating temperatures which might result in expansion problems should be considered early in the design. Also, this situation often has an appreciable effect on the structure surrounding the bearing.

Thin-race bearing races shrink or expand on a

Thick to Thin . . .

Light-section bearings were born in the period just before World War II. In small aircraft, bushings were still adequate. But as aircraft grew in size and control loads increased, friction losses in control systems became critical. Aircraft designers turned to antifriction bearings.

The need for a suitable bearing resulted in the familiar "torque-tube" series. These bearings were supplied without a retainer and were intended for oscillatory operation only. Later, when the helicopter became a practical vehicle, a different light-section bearing was needed, one with a much larger bore than the "torque-tube" series could provide. Again a special series of bearings was designed and manufactured to meet the need. These are popularly referred to as "helicopter bearings."

Although there were some developments in the electromechanical field during World War II, the major developments in radar, guidance systems, and similar equipment have come about since that time. In this field a need developed for a bearing which, although capable of carrying load, was intended primarily as a positioning device which was capable of very precise operation.

Initially, torque-tube bearings and helicopter bearings were used. Almost immediately, however, problems developed. Either the necessary precision was not obtainable, or size limitations prevented the use of the best design. It was at this point that thin-race bearings came into the picture.

one-to-one basis; i.e., if an outer race is shrink-fitted into a housing by 0.001 in., both the OD and the ID of the outer race are reduced by 0.001 in. This condition has a noticeable effect upon bearing operation at temperatures other than installation temperature. For example, assume that a bearing is installed at room temperature with an internal bearing fit-up of 0.001 in. loose and a line-to-line fit between the housing and the outer race. When the temperature drops to a point where the housing bore is reduced 0.001 in., the ID of the bearing outer race will also be reduced 0.001 in. The internal fit-up of the bearing then becomes line-to-line, rather than 0.001 in. loose. A further reduction in temperature results in the bearing being preloaded.

This is a difficult problem, and experience has shown that almost every case must be individually evaluated. The following methods of allowing for temperature effects have been used with some success. They are not, however, meant as a cure-all for all applications.

Loose internal fit-up can be used, in conjunction with the other methods outlined below, to compensate for temperature differentials. But a bearing with too much internal looseness has a tendency to rock or seesaw, so that in applications where stability is critical, this condition is unacceptable.

Steel Liners: Where space allows, this method appears to be the most effective and the most workable solution. However, the liner must be thick enough to resist any movement of the nonferrous housing. Also, the liner should be locked into the housing uniformly throughout its circumference, rather than locally, Fig. 3.

Rubber O-Rings: In this case, the bearing is backed up by O-rings mounted in grooves, Fig. 4. The grooves are designed to allow for distortion of the O-rings due to differential expansion but should not allow clearance to develop between the housing and O-ring or between the O-ring and the bearing race. This type of mounting is suitable only for relatively small bearings (2 to 6-in. bore) under light loads.

Floating Bushings: In this type of mounting, soft rubber bushings are used in conjunction with the bearing hold-down bolts, Fig. 5. The bearing is not rigidly clamped axially but is left slightly loose. During temperature changes, the clamping bolts move with the housing and distort the rubber bushing, without affecting the bearing. Special care in installation is required in this type of mounting.

Direct Mounting: Steel bearings may be mounted directly in nonferrous housings. This type of installation has been used with some success. However, thermal expansion characteristics of the dissimilar metals result in a high degree of unpredictability in bearing behavior.

Frictional Torque: There are so many variables in connection with this problem that it is impossible to solve with any great accuracy.

For approximation a friction factor of 0.003 is generally used for all ball bearings. To have a common base to work from in considering torque, it is best to refer to permissible torque under some known

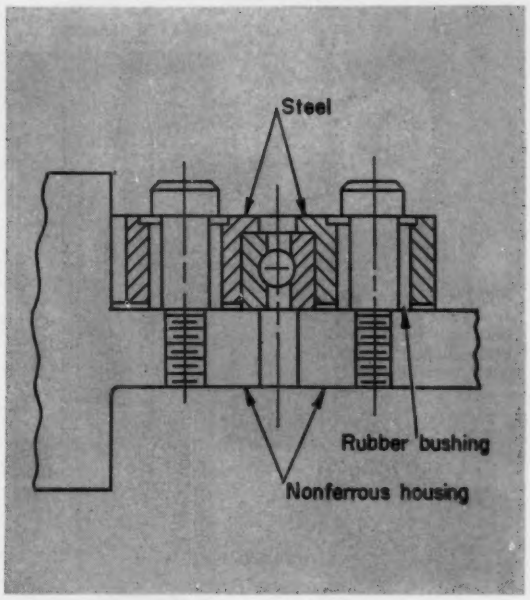


Fig. 5—Rubber bushings used with bearing hold-down bolts in application where bearing and housing are of dissimilar metals. This requires great care in installation.

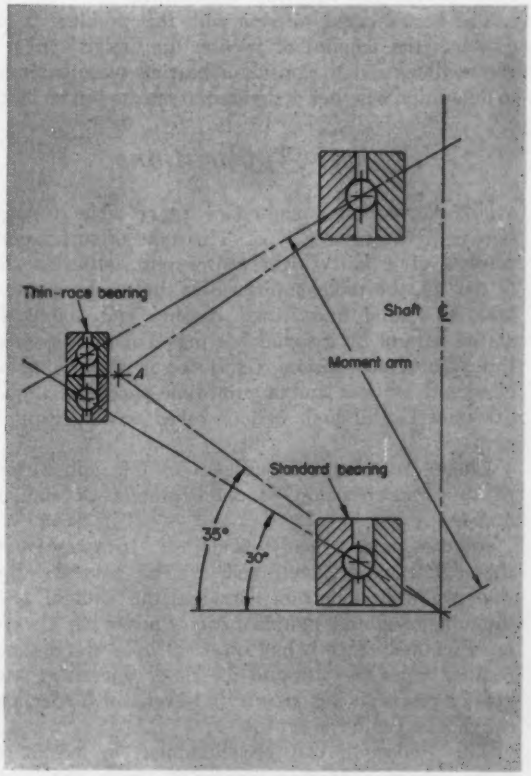


Fig. 6—An example of height reduction available in a vertical-shaft application using thin-race bearings. Point *A* is pitch-diameter location of single thin-race bearing, which would be sufficient for a slow-speed application. In addition to reducing height, thin-race bearings provide greater accuracy than possible with conventional bearings.

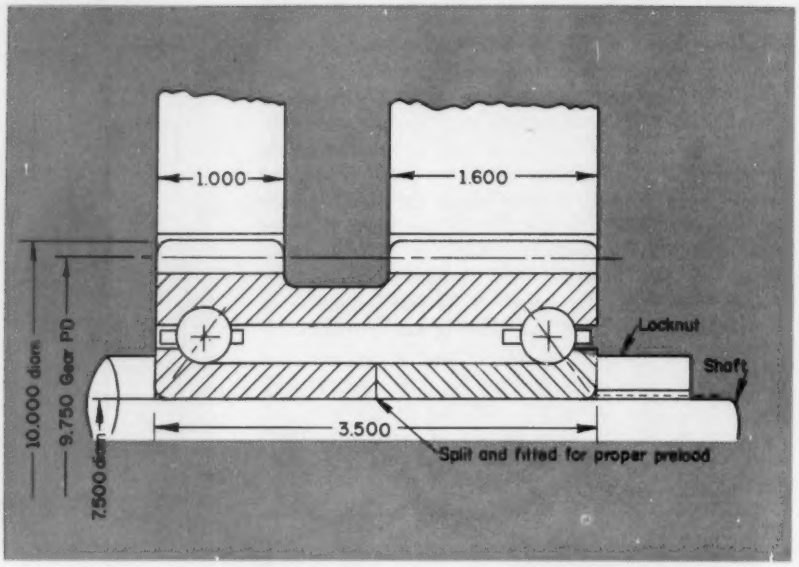


Fig. 7—A special-purpose application of a thin-race bearing, with the external gear integral with the outer bearing race.

external load on the bearing. Where there is a possibility of bearing distortion in the free state, all torque checks should be made in a fixture or some other device that will true the bearing.

The best method to cope with this problem is to establish the amount of friction the design can accommodate, and to consult a bearing manufacturer to determine whether design requirements can be met.

Typical Applications

The conventional method of rotary table suspension is of the spindle type. This type of suspension consists of a fairly rigid center post, attached to, or part of, the table, supported at the top by a combination radial and thrust bearing and stabilized at the bottom by a radial bearing. For high speeds, this type of suspension is still the most acceptable. However, for low and intermediate speeds, a single thin-race Gothic-arch ball or roller bearing can be used.

There are several advantages in this application of thin-race bearings to rotary tables or similar devices.

Anything under load will deflect. In many cases this deflection is small and can be ignored. For example, the deflection between the spindle and the table of spindle-mounted rotary tables has always been ignored, since it had no effect upon the desired results. Since the demand for closer tolerances and greater precision has grown, however, this deflection can no longer be tolerated.

This deflection can be eliminated by use of a large thin-race bearing positioned under the load. Thus, a very high degree of stability and rotational accuracy can be obtained. Recently a rotary inspection table was made available which is capable of accuracies to 5 sec of arc.

In addition to providing greater accuracy, this application of the Gothic-arch thin-race bearing reduced the table support height, making a more compact installation. Fig. 6 illustrates the reduced height possible with such an installation.

In many applications where a sleeve bushing might be used, thin-race bearings offer advantages in precision axial alignment, turning resistance, maintenance, etc. Under correct design conditions they can be used with only a negligible increase in section thickness or over-all size.

Thin-race bearings can also be used in special-purpose parts. Such an application is shown in Fig. 7.

ACKNOWLEDGMENT

Lead photo credit Messinger Bearings Inc.

They say . . .

"The project manager is faced with the task of organizing and controlling intangibles; such a role is basically foreign to the engineer. From his earliest training he has been impressed with the value of scientific analysis. Hard facts are the tools of his trade. By marshaling these facts skillfully, he can follow a single problem through to its solution. But as a project manager he finds himself marshaling pieces of preliminary or tentative information; juggling several problems at once; compromising one requirement for the benefit of another; making decisions that are often based on a broad fund of experience and judgment rather than on specific knowledge. It becomes increasingly difficult, therefore, to find engineers capable of managing development programs."—J. LEE ATWOOD, *president, North American Aviation Inc., Los Angeles, Calif.*

Multiple-Speed Gear Transmission

Coaxial gears of different ratios are driven by separate pinions on a common input shaft. One gear drives while the other idles in the opposite direction. Two input speeds of reversing motor provide four output speeds in the same direction of rotation. Inside gear set is a right-hand assembly; outside gear set is left hand.

Spiroid Gearing

Part 2—Durability, Strength, and Efficiency

WOODROW D. NELSON, Chief Engineer
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WHAT is the capacity or rating of a Spiroid gear set? Once the dimensions of a gear set are known, the next logical step is to verify its capacity, particularly if the set will operate under heavy loads, is likely to be overloaded, or may be subjected to impact and shock loads.

This article shows how to calculate tooth-surface durability, tooth breaking strength, and efficiency of Spiroid gear sets. General operating characteristics, gear geometry, and blank proportions are covered in Part 1 of this series.

Failure Criteria

Any discussion of Spiroid gear-set ratings necessarily involves a definition of the criteria of failure. Unfortunately, there is no single criterion that is sufficient for all cases. Generally speaking, important requirements are:

1. **Strength:** The teeth must not break or undergo plastic deformation. Blanks and mountings, too, must support and transfer the loads without breakage or excessive deformations.
2. **Durability:** The tooth surfaces must not show excessive wear, fatigue cracks, or other recognized forms of deterioration. Similar remarks apply to the bearings.
3. **Efficiency:** Good design practice for power-transmission drives includes the calculation of efficiency and the use of positive design measures to make the efficiency as high as possible. Inefficiency overloads an engine or motor, causes loss of output torque, and often raises the gear box temperature to the point of overheating. An exception is gear sets designed for self-locking where operating requirements impose definite limitations on efficiency.

4. **Temperature:** Overheating cannot be tolerated primarily because excessive temperature rise affects the life and lubricating properties of oil and, at times, even the physical properties of the gear materials as well.
5. **Quietness:** This is a difficult psychological criterion to predict but often a practical requirement. Noisy gears, however, usually reflect on accuracy, workmanship, or design.

Minimum requirements in many applications are that the gears must not break or wear out during expected life. Other requirements are size, weight, and cost, all of which depend upon the type of gears, materials, and accuracy needed.

Analytical Approach to Durability

At this point, it may be helpful to summarize how gear tooth action influences surface durability.

The contact line of a pair of engaging gear teeth moves with respect to each tooth surface. The velocity component of this motion in a direction normal to the contact line is known as the "normal sweep velocity." In general, it will be different for each mating gear tooth. The normal sweep velocity is important since it represents the rate at which freshly lubricated cool surfaces enter the mesh. It is also a measure of the oil-film building ability of the mesh.

The sliding velocity of mating gear teeth is a point function and represents the vector difference between the absolute velocities of the gear teeth at a point of conjugate contact. The magnitude of the total sliding velocity is important since it is proportional to the generated heat.

For analysis of the influence of tooth action on surface durability of various gear types, the basis of comparison should be the slide-sweep conditions. Parallel and intersecting-axes gearing are in the same general category insofar as slide-sweep conditions are concerned. Skew axis gearing has less favorable slide-sweep conditions, not only because the sliding velocity increases with axis offset, but also because the contact lines are of such geometry that the normal sweep velocity is small.

Sliding action in Spiroid gearing lies between the minimum sliding conditions of bevel gears and the maximum sliding of worm gears. Normal sweep velocities of Spiroid gears are similar to bevel gears and both are considerably higher than worm gears. However, the combination slide-sweep conditions for Spiroid, as with hypoid and worm gears, are such that surface durability depends largely on the proper combination of mating materials and lubrication. Durability is calculated for a specific combination of materials and lubricants and not for each member separately.

Tooth-surface failure in high-sliding gears is a very complex phenomenon. It depends upon several interdependent variables. Most causes of failure, however, fall into one of the following categories:

1. Rapid removal of metal from softer member. The surface of the softer metal appears bright and shiny or scratchy, depending upon the hardness and finish of mating part. Depth of wear exceeds 0.002 or 0.003 in. of initial wear-in on new bronze gears or half that amount on hardened steel gears. A feather edge develops at tooth tips early in service life. These conditions are characteristic of overloading.
2. Development of fine surface and subsurface cracks. Eventually such cracks lead to progressive pitting, flaking, and gross surface destruction. Gears failing in this manner often exceed 300 or 400 hours of operation before signs of surface distress appear. This type of failure is attributed to fatigue.
3. Scoring, seizing, welding, pick-up. All of these types of failure usually exhibit a transfer of metal from one tooth surface to another, giving the appearance of a rough metallic smear.

Field and laboratory testing of Spiroid gears has been conducted with the aim of arriving at surface durability ratings which will minimize or eliminate

Nomenclature

A = Approximate length of contact zone, in.
C = Center distance, or offset, in.
C_R = Contact ratio
E_G = Efficiency with gear driving
E_P = Efficiency with pinion driving

h_{kr} = Working depth perpendicular to pinion axis, in.
K_v = Sliding velocity factor
K_w = Allowable wear factor, lb of tooth load/in. of contact line/in. of relative radius of curvature
L = Conical lead of pinion, in.
L_{C1} = Equivalent cylindrical lead on low side, in.

l_c = Total length of contact line, in.
M = Materials factor
m_G = Gear ratio
= N/n
N = Number of teeth on gear

n = Number of threads on pinion
P_o = Allowable output power, hp
R_e = Effective radius of gear, in.
R_G = Pitch radius of gear, in.
r_m = Mean radius of pinion at midface and at half the working depth, in.
r_P = Pitch radius of pinion, in.

T_G = Output torque of gear, lb-in.
T_{GB} = Output torque of gear at breaking load lb-in.
T_{GO} = Output torque on gear at allowable tooth load W_{GO}
V_s = Relative sliding velocity, fpm
W_{GO} = Allowable wear load on tooth of gear, lb

x_m = Co-ordinate to plane of mean radius of pinion, in.
θ = Position angle of mean point, deg
ρ_G = Radius of curvature of gear tooth, in.
ρ_P = Radius of curvature of pinion thread, in.
ρ_o = Relative radius of curvature

σ = Pitch-point location angle on gear, deg
τ = Angle between an element of pinion pitch cone and pinion axis, deg
ϕ_1 = Tooth axial pressure angle (low side), deg
ϕ_2 = Tooth axial pressure angle (high side), deg
ψ_G = Gear spiral angle, deg

ψ_m = Mean spiral angle, deg
ψ_P = Pinion spiral angle, deg
ω_G = Angular velocity of gear, rpm
ω_P = Angular velocity of pinion, rpm

failures of all types. This experimental work is summarized in the form of wear-factor curves, Fig. 13.

Since optimum design proportions vary with job requirements, the geometry of a gear set is the key in calculating power capacity. Based on this approach, allowable horsepower at acceptable wear levels for gears operating from 8 to 10 hr per day with no recurrent shock load is (see Nomenclature):

$$P_o = \frac{T_{GO}\omega_G}{63{,}000} \tag{23}$$

where the allowable output torque is

$$T_{GO} = K_w \rho_o l_c R_e \tag{24}$$

and the allowable tooth load on the gear in a plane of rotation is

$$W_{GO} = K_w \rho_o l_c \tag{25}$$

Experimental evidence indicates little difference in horsepower capacity between the high and low-side pressure angles when both members are properly mounted in rigid supports. The low-side tooth profile is analyzed for wear since it normally is chosen as the drive side to minimize shaft deflection and stress.

The starting point in calculating allowable tooth load W_{GO} is to determine the equivalent cylindrical lead,

$$L_{C1} = L(1 - \tan\tau \tan\phi_1) \tag{26}$$

Next, angle θ, Fig. 14, is determined from

$$\tan\theta = \frac{\frac{m_G L_{C1}}{2\pi} - C}{x_m} \tag{27}$$

Approximate radii of curvature of the gear tooth and pinion thread are

$$\rho_G = x_m \sec\theta \tag{28}$$

$$\rho_P = \frac{r_m}{\tan\phi_1 \cos^3\theta} \tag{29}$$

While these radii of curvature are sufficiently accurate for durability calculations they may not be accurate enough for the solution of other geometrical problems.

Relative radius of curvature, ρ_o, can now be calculated from

$$\frac{1}{\rho_o} = \frac{1}{\rho_G} + \frac{1}{\rho_P} \tag{30}$$

For convenience, average design values of relative radii of curvature can be read directly from the curves of Fig. 15.

Next, the effective load-carrying length of tooth-contact line must be determined. Contact lines on Spiroid gears are almost radial lines on the pinion, particularly on the low-side profile. Length of contact line between any pair of engaged teeth is very nearly equal to the working tooth depth.

Total length of tooth-contact line, l_c, is a function of the number of teeth in simultaneous contact (contact ratio) and the tooth working depth, h_{kr}. Dimension A, Fig. 16, must be found first. It can be determined graphically or may be assumed to be

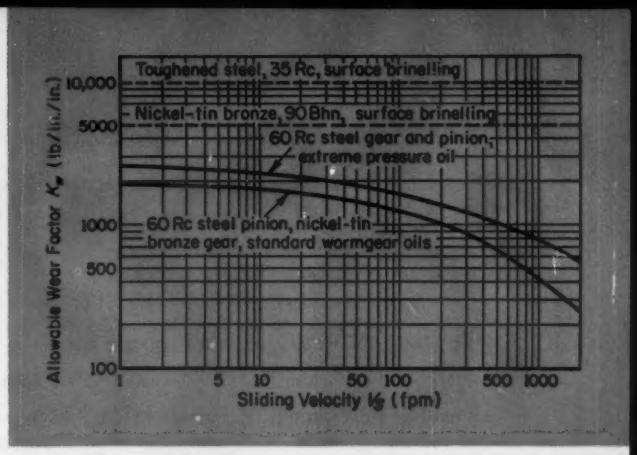


Fig. 13—Allowable wear factors for durability calculations.

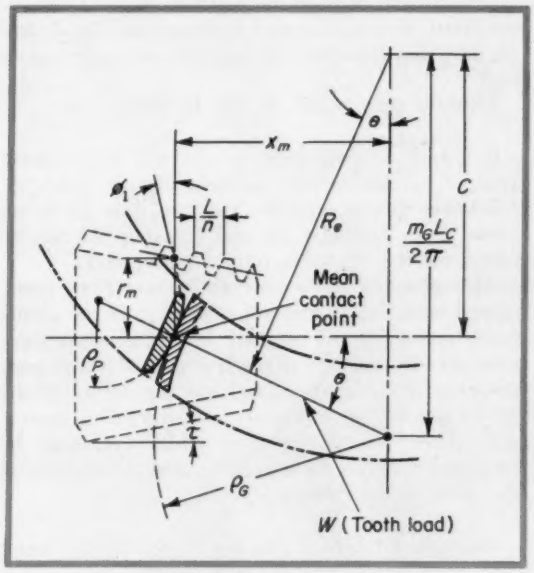


Fig. 14—Geometrical relations for durability equations.

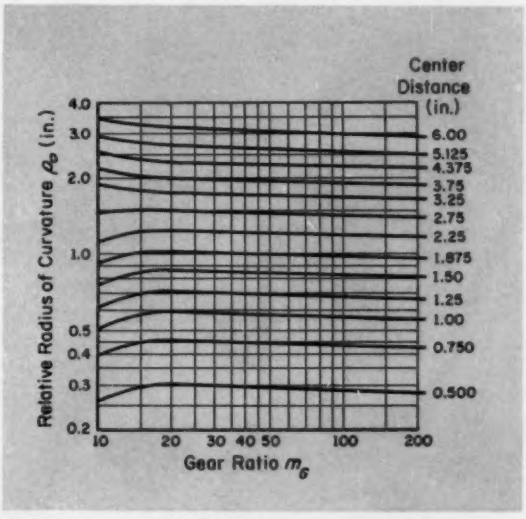


Fig. 15—Relative radius of curvature.

0.60C for standard proportions. Then, contact ratio can be calculated from

$$C_R = \frac{A}{\frac{L}{n}} \tag{31}$$

Finally the total length of tooth-contact line is

$$l_c = C_R h_{kr} \tag{32}$$

Allowable wear factors K_w given in Fig. 13 represent results of many tests. Any value of K_w is a function of sliding velocity and mating materials. Sliding-velocity factors K_v for standard proportions are plotted in Fig. 17. Sliding velocity is determined by multiplying factor K_v by pinion rpm.

Accordingly, a value of K_w from Fig. 13 can be combined with ρ_o, C_R, and l_c, Equations 30, 31, and 32, to solve Equation 25 for allowable gear tooth load.

Effective gear radius R_e can be found from

$$R_e = \frac{m_G L_{C1}}{2\pi} \cos\theta \tag{33}$$

Allowable torque capacity T_{GO} can now be determined from Equation 24, and Equation 23 can be solved for the allowable output horsepower.

Also affecting surface durability are such interrelated variables as the fatiguing effect of the elastic wave preceding the contact line, the momentary reduction in material strength due to elevated temperature at the contact line, and the ability of the oil to provide the necessary boundary-film protection. These effects are most easily evaluated by empirical methods, such as were used in establishing the wear factor curves, Fig. 13.

Example 1: A 63:2 gear set has a 2.25 in. center distance and standard proportions. Pinion speed is 1750 rpm for service of 8 to 10 hr per day. Determine the output horsepower and torque capacity if both members are steel of 60 Rc surface hardness, and extreme pressure oil is the lubricant.

Assume that, from equations given in Part 1 of this series, the following calculated values are obtained: Lead $L = 0.472$ in., $x_m = 1.861$ in., $r_m = 0.623$ in., and $h_{kr} = 0.194$ in. Also, assume $A = 1.45$ in. is determined graphically. From Equations 26 and 27,

$$L_{C1} = 0.472(1 - 0.0875 \times 0.176) = 0.465 \text{ in.}$$

$$\tan\theta = \frac{\frac{31.5(0.465)}{2\pi} - 2.25}{1.861} = 0.0430$$

and $\theta = 2$ deg 28 min.

From Equations 28, 29, and 30,

$$\rho_G = 1.861(1.001) = 1.861 \text{ in.}$$

$$\rho_P = \frac{0.623}{0.176(0.999)^3} = 3.55 \text{ in.}$$

$$\frac{1}{\rho_o} = \frac{1}{1.861} + \frac{1}{3.55}$$

Thus, $\rho_o = 1.22$ in.

From Equations 31 and 32,

$$C_R = \frac{1.45}{\frac{0.472}{2}} = 6.15$$

$$l_c = 6.15(0.194) = 1.192 \text{ in.}$$

From Fig. 17, $V_s = 0.273\ (1750) = 478$ fpm which gives $K_w = 1040$, Fig. 13. Now, from Equation 33

$$R_e = \frac{31.5(0.465)}{2\pi} 0.999 = 2.34 \text{ in.}$$

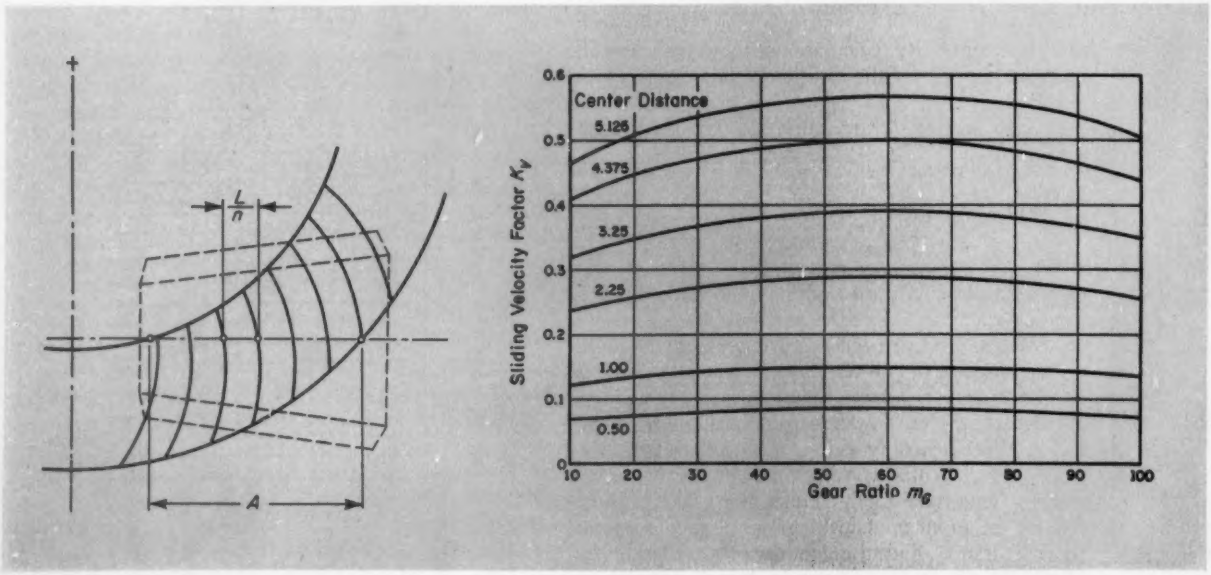


Fig. 16—Tooth layout and geometry for contact-ratio calculations.

Fig. 17—Sliding-velocity factors. Sliding velocity is determined by multiplying angular speed of pinion (rpm) by factor K_v.

When K_w, ρ_o, l_c, and R_e are substituted into Equation 24,

$$T_{GO} = (1040)1.22(1.19)2.34 = 3530 \text{ lb-in.}$$

which is the solution for torque capacity.

From Equation 23, the allowable power is

$$P_o = \frac{3530\,\frac{1750}{31.5}}{63{,}000} = 3.11 \text{ hp}$$

Example 2: Design conditions are same as Example 1, except that the pinion is steel and the gear is bronze.

Under these conditions, $K_w = 660$ at 478 fpm, Fig. 13. When this value is substituted in Equations 24 and 23, the torque capacity is

$$T_{GO} = (660)1.22(1.19)2.34 = 2240 \text{ lb-in.}$$

and the allowable power is

$$P_o = \frac{2240\,\frac{1750}{31.5}}{63{,}000} = 1.98 \text{ hp}$$

Empirical Durability Calculations

The foregoing procedure can be applied to find the capacity of any Spiroid gear set, standard or nonstandard. However, as often as not, the problem takes the form of determining the approximate size of a standard gear set when the horsepower, speed, and ratio are given.

Under these conditions, an empirical rating equation may be used to find the required center distance of a completely standard set:

$$P_o = F_M F_C F_\omega F_r \qquad (34)$$

where F_M = materials factor, F_C = size factor, F_ω = speed factor, and F_r = ratio factor. Materials factor $F_M = 0.002$ when both pinion and gear are hardened steel and extreme pressure lubricants are used; $F_M = 0.0012$ when the pinion is hardened steel, the gear is nickel bronze, and worm gear lubricants are used.

Size factor F_C is expressed as a function of center distance by

$$F_C = C^{2.68} \qquad (35)$$

where $1 < C < 5$ in. Since C is unknown here, Equation 34 is rearranged and solved for F_C, after

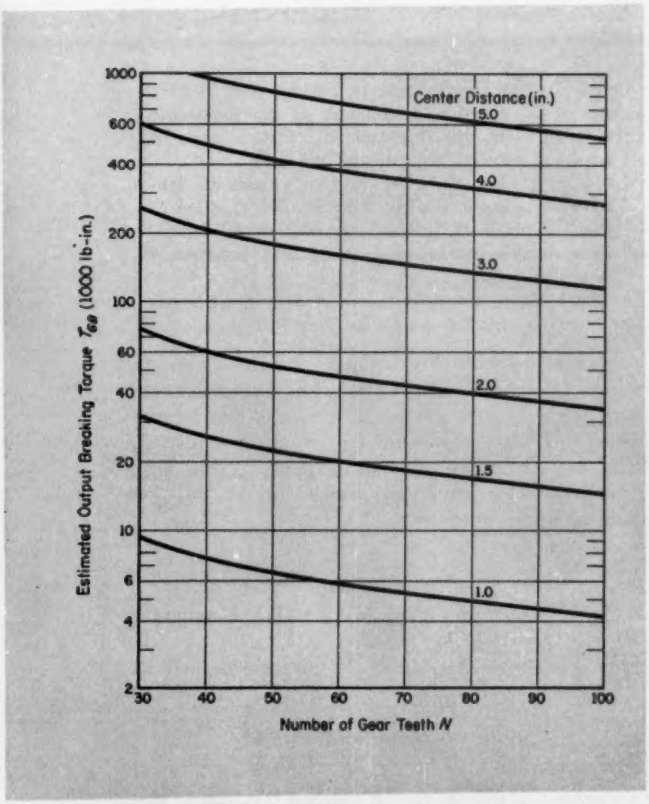
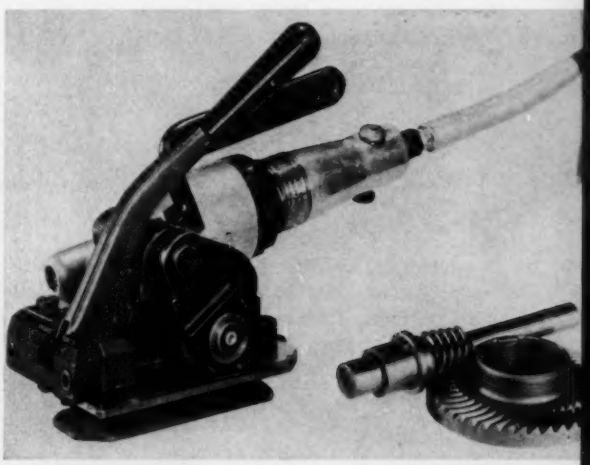
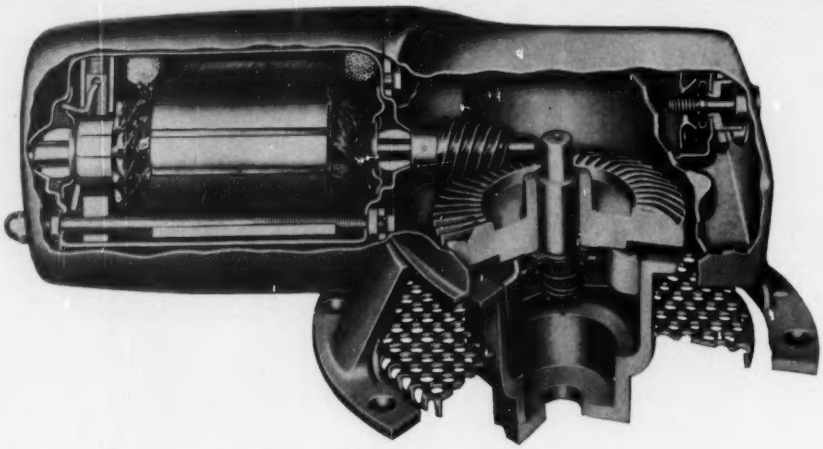


Fig. 18—Typical breaking-strength curves. Curve plots are based on combination of steel gear and pinion of 30 Rc core hardness and standard proportions. For extremely rigid blanks, bearing mountings, and housing, multiply curve values by 1.0 for low-side driving and by 0.6 for high-side driving. For average design rigidity, multiply curve values by 0.5 for low-side driving and by 0.3 for high-side driving.



Heavy-Duty Reduction Drive

Small gear set in strapping tool is subjected to 3400 lb-in. of stall torque during each cycle of operation, and occasionally to torques as great as 6000 lb-in. Gear ratio is 46:3 and gear diameter is 3 in. Both gear and pinion are straddle mounted. They are steel of 60 Rc surface hardness and have generous fillets at the roots of the teeth for maximum resistance to fatigue failure. (Photo, courtesy Signode Steel Strapping Co.)



High-Production Gear Assembly

Gear blank, teeth, and clutch lugs of Spiroid gear in electric-starter drive for lawn-mower engine are die-cast aluminum and require only a combined spot face and reaming operation to finish the gear for assembly. Pinion blank, of free-machining brass, is made on an automatic screw machine. Spiroid threads are cut in a secondary operation on an automatic chasing lathe. The pinion is pressed directly on the motor shaft and is then cross drilled and pinned. (Photo, courtesy Fairbanks, Morse & Co.)

which Equation 35 is solved for C.

Speed factor,

$$F_\omega = \omega_P^{0.546} - 7 \qquad (36)$$

where $100 < \omega_P < 3000$ rpm.

Ratio factor,

$$F_r = \frac{56}{m_G^{0.64}} - 1 \qquad (37)$$

where $10 < m_G < 100$.

Example 3: Determine the approximate size of a gear set required to deliver 3.11 hp at 1750 rpm pinion speed if the reduction is 31.5:1.

From Equation 34,

$$F_C = \frac{P_o}{F_M F_\omega F_r} = \frac{3.11}{0.002\,(52)\,(2.96)} = 10.1$$

Hence, from Equation 35, $C = (10.1)^{1/2.68} = 2.37$ in., which agrees well with the given center distance of Example 1, $C = 2.25$ in.

Breaking-Strength Ratings

Several important points should be kept in mind when designing Spiroid gearing.

1. The deflection of the gear blanks, mountings, and housing have considerable influence on the breaking strength. The larger the deflection the greater the tendency for the teeth to cam out of mesh and lose load-carrying effectiveness.
2. When the pinion is made of steel and the mating gear of bronze, the gear always fails first. When both are made of steel and are approximately equal in tensile strength, failure occurs almost simultaneously.
3. Case-hardened gears begin to fail by case cracking caused by excessive deformation of the tooth-core material. The breaking strength of such gears is based on physical properties of the core.
4. The first sign of failure in bronze and through-hardened gears is a slight indenting or brinelling of the working tooth surface. Actual structural failure, however, does not occur until the load is increased by several times.
5. The mode of structural failure of Spiroid teeth and threads is regarded mainly as shear.

Present methods of calculating breaking-strength ratings provide, at best, only a fair approximation, particularly because of the influence of the rigidity factor, Fig. 18. However, an empirical equation, based on laboratory and field experience, has been developed. This equation, which applies only to standard proportions, is

$$T_{GB} = \frac{M C^3}{N^{0.64}} \qquad (38)$$

where $1 < C < 5$, $30 < N < 100$, and materials factor M is given in Table 1.

Fig. 18 shows the family of curves obtained by

Table 1—Materials Factors*

Steel Gear		Bronze Gear	
Core Hardness (Rc)	Material Factor, M	Tensile Strength (psi)	Material Factor, M
20	67,500	35,000	54,000
30	81,000	90,000	108,000
40	117,000		
50	162,000		
60	203,000		

*For steel pinion with core hardness of 30 Rc and surface hardness of 60-62 Rc.

plotting Equation 38 when both pinion and gear are steel of 30 Rc core hardness.

Example 4: Consider again the problem of Example 1. If materials factor $M = 81{,}000$ (from Table 1 for case hardness of 60 Rc and core hardness of 30 Rc), what is the breaking-torque rating with and without allowance for rigidity?

From Equation 38,

$$T_{GR} = \frac{81{,}000(2.25)^3}{(63)^{0.64}} = 65{,}000 \text{ lb-in.}$$

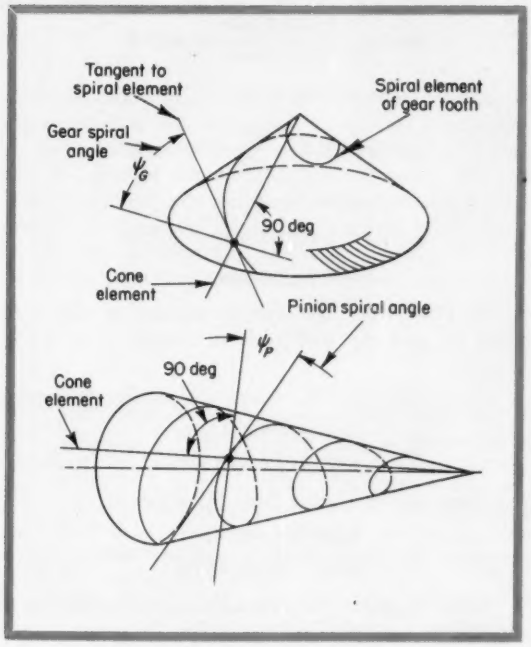


Fig. 19—Pinion and gear spiral angles.

If the gear set is a low-side drive of average design rigidity, a rigidity factor of 0.5 applies, Fig. 18. Thus, a breaking torque of about 32,500 lb-in. might be expected from ordinary design.

These values of breaking torque may well be read directly from Fig. 18. Equation 38, however, has wider application. Additional charts like Fig. 18 to suit other combinations of materials and hardnesses are convenient for those combinations that are used over and over. They are readily constructed from Equation 38.

Gear-Pair Efficiencies

Spiroid-gear drives have efficiency characteristics similar to those of cylindrical wormgear drives in several ways. Efficiency equations are of similar form, low gear ratios and/or small pinions lead to higher efficiencies, self-locking increases with gear ratio, and efficiencies are influenced by nongeometric factors, such as load, speed, materials, and lubrication.

For a specified gear ratio and gear diameter, however, the Spiroid system offers somewhat greater design latitude in selecting center distance and pinion diameter, and, consequently, more freedom in designing for optimum efficiency. Basic efficiency equations for Spiroid gears are

$$E_P = \frac{\cos \phi_n + \mu \cot \psi_G}{\cos \phi_n + \mu \cot \psi_P} \quad (39)$$

$$E_G = \frac{\cos \phi_n - \mu \cot \psi_P}{\cos \phi_n - \mu \cot \psi_G} \quad (40)$$

$$\mu = \frac{(1 - E_P)\cos \phi_n}{E_P \cot \psi_P - \cot \psi_G} \quad (41)$$

For self-locking, $E_G = 0$. Hence, from Equation 40,

$$\cos \phi_n - \mu \cot \psi_P = 0 \quad (42)$$

If Equation 42 is rearranged,

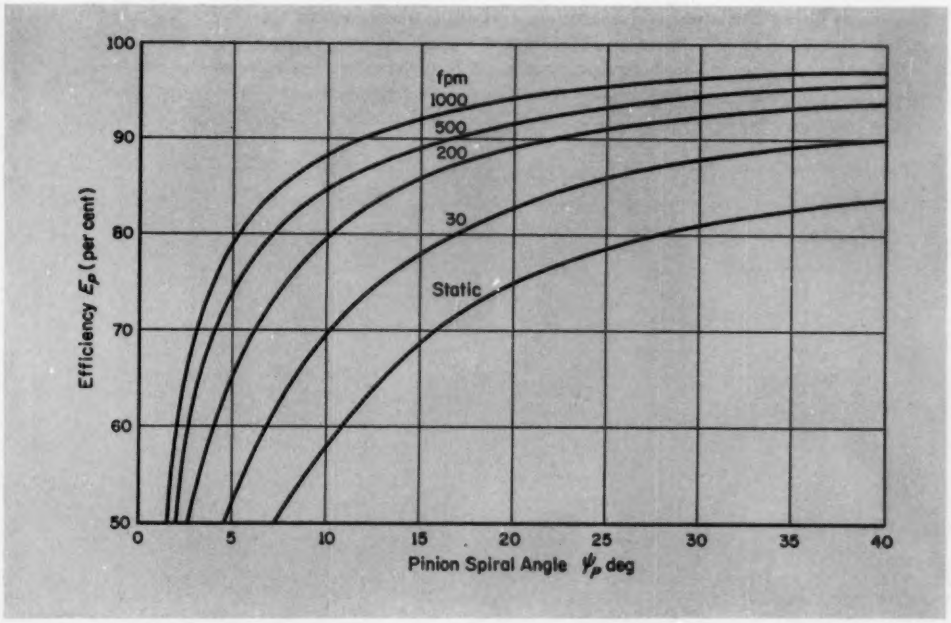


Fig. 20 — Efficiencies of standard Spiroid gears with pinion driving. Curve plots are based on hardened steel for both pinion and gear, extreme-pressure oil, low-side driving, and standard proportions of $\phi_t = 10$ deg and $\psi_G = \psi_P + 50$ deg.

$$\cot \psi_P = \frac{\cos \phi_n}{\mu} \tag{43}$$

which defines the locking spiral angle for the pinion.

Efficiency, like sliding velocity, is a point function. Hence, a specific point upon which to base calculations must be selected in such a way that it represents average conditions in the field of contact. For precise work, this selection involves a tedious and complicated contact analysis, which is recommended only for critical jobs.

A reasonable compromise is to base the efficiency calculations on the pitch-point parameter values, since most of these values are usually available from previous calculations. The error is generally small, and the calculated efficiency value is usually less than the actual efficiency.

The spiral angle of the pinion at the pitch point is found from

$$\tan \psi_P = \frac{L \sec \tau}{2 \pi r_P} \tag{44}$$

where L and r_P are given by Equations 8 and 10, Part 1, and τ is the angle between an element of the pinion pitch cone and the pinion axis.

The spiral angle of the gear at the pitch point is found from

$$\sin \psi_G = m_G \frac{r_P}{R_G} \sin \psi_P \tag{45}$$

where m_G is the gear ratio, N/n, and ratio R_G/r_P is established by Fig. 11, Part 1.

A convenient approximation for the gear spiral angle, expressed as a function of angle σ (Part 1), is

$$\psi_G = 90 - (\sigma_p - \psi_P) \tag{46}$$

The normal pressure angle is found from

$$\tan \phi_n = \tan \phi_x \cos \psi_P \tag{47}$$

where the axial pressure angle, ϕ_x, is either the low-side pressure angle, ϕ_1, or the high-side pressure angle, ϕ_2. The geometric meaning of the spiral angles is shown in Fig. 19.

Typical efficiencies for standard Spiroid gear sets are given in Fig. 20. Coefficient of friction versus sliding velocity is plotted in Fig. 21. Sliding velocity for standard sets can be found from Fig. 17.

Example 5: For the design problem of Example 1, $R_G = 2.525$ in., $r_P = 0.643$ in., $m_G = 31.5$, $L = 0.472$ in., $\phi_1 = 10$ deg, $\phi_2 = 30$ deg, $\tau = 5$ deg, and $\sigma = 40$ deg. If the pinion speed is 1750 rpm, what are the efficiencies and the associated friction properties?

From Equations 44, 45, and 47

$$\tan \psi_P = \frac{0.472(1.004)}{2\pi(0.643)} = 0.1172$$

$$\psi_P = 6 \text{ deg } 41 \text{ min}$$

$$\sin \psi_G = 31.5 \frac{0.643}{2.525} 0.1164 = 0.930$$

$$\psi_G = 68 \text{ deg } 27 \text{ min}$$

$$\tan \phi_{n1} = 0.1763(0.993) = 0.1750$$

$$\phi_{n1} = 9 \text{ deg } 56 \text{ min}$$

At 1750 rpm, the sliding velocity is 485 fpm, Fig. 17, and the coefficient of friction $\mu = 0.036$, Fig. 21.

From Equation 39, when the pinion is driving

$$E_P = \frac{0.985 + 0.036(0.395)}{0.985 + 0.036(8.53)} = 0.772$$

If the gear is driving, from Equation 40,

$$E_G = \frac{0.985 - 0.036(8.53)}{0.985 - 0.036(0.395)} = 0.700$$

From Equation 41 the self-locking coefficient of friction is $\mu = 0.985/8.53 = 0.115$.

Part 3, the concluding article of this series, will discuss materials, mounting design details, tolerances, lubrication, and application factors.

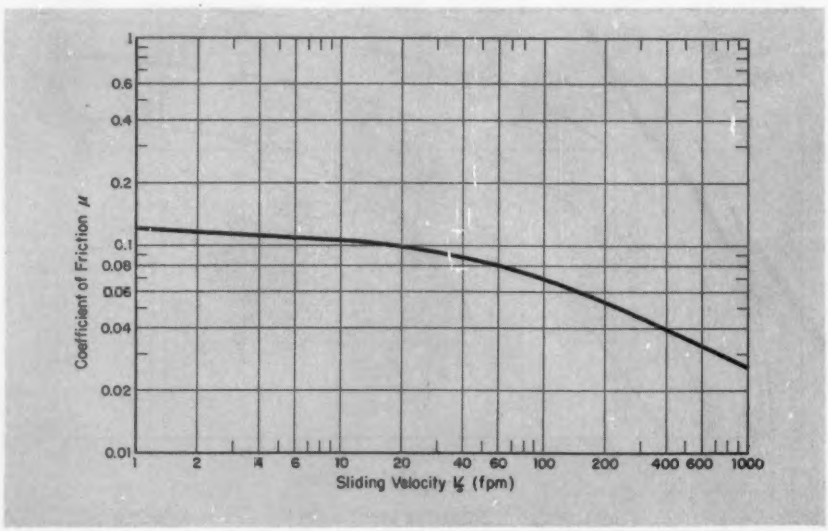
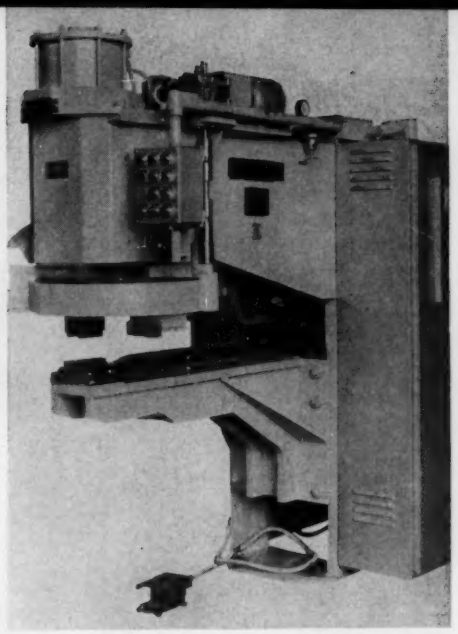
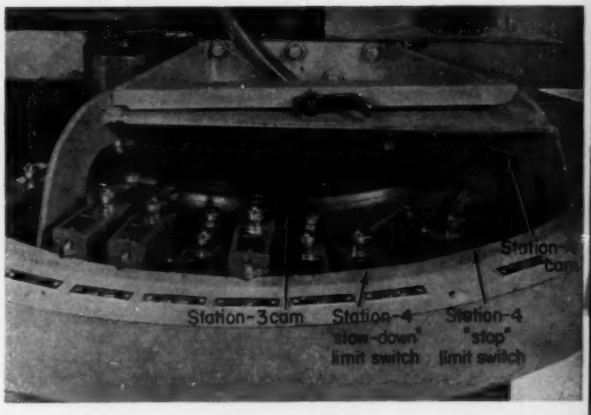


Fig. 21 — Coefficient of friction vs. sliding velocity. Curve plot applies to combination of hardened steel gear and pinion lubricated with extreme-pressure oil.

Pushbuttons Select Programs In Multi-Station Welder

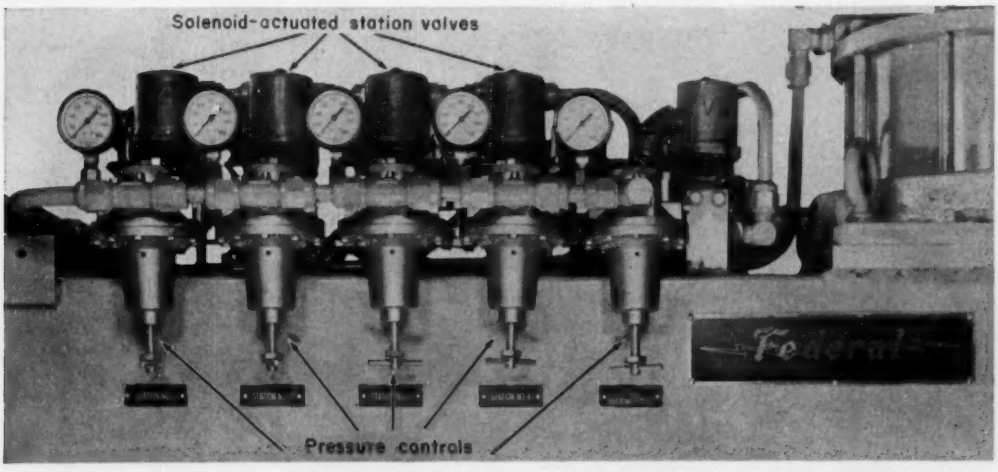


OFF-THE-SHELF components program a dial-station welder. Limit switches, hold-in relays, valves, and a timer are connected to control any one of four welding programs that can be selected by pushbutton. Pressure, temperature, weld time, heat time, slope, and other variables are automatically preselected when the program is chosen. Control of piece insertion and alignment was kept in the hands of the operator because of the judgment required.



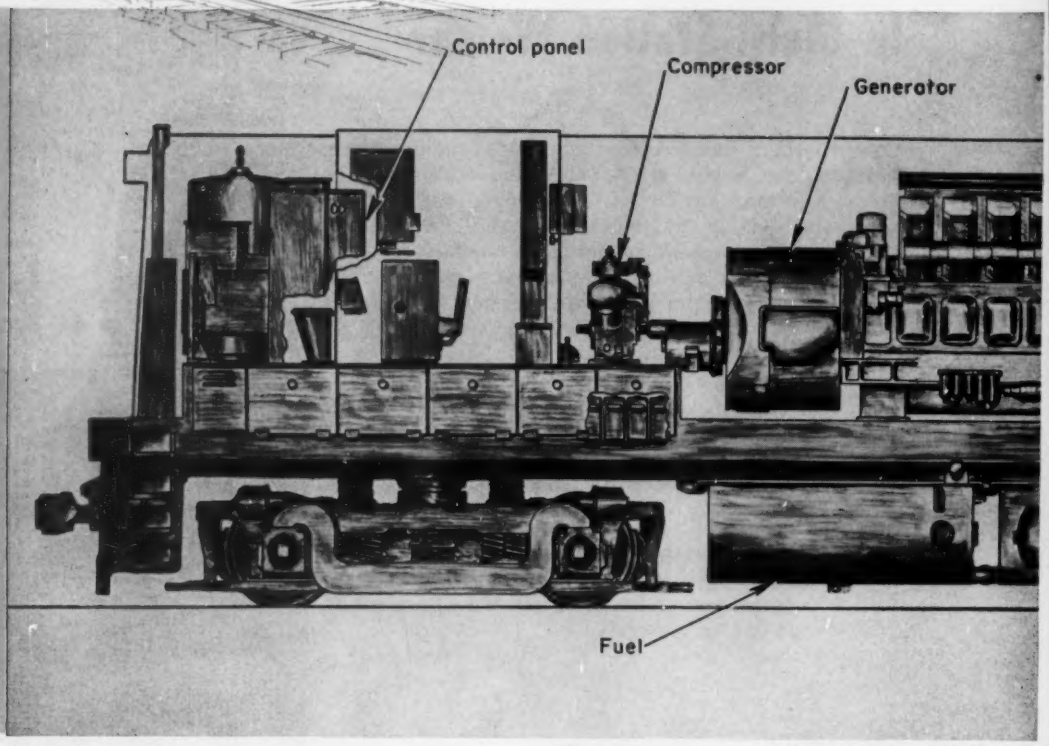
LIMIT SWITCHES control slow-down and stop of the indexing dial. Slow-down switches trip a relay to change wiring sequence of the motor. Four cams revolving with the dial bull gear actuate the eight switches. Stepped position of cams and switches gives each cam clearance to pass all switches except the two for its station. Although all limit switches are tripped on every rotation of the dial, only the set selected by pushbutton is carrying current.

STOCK VALVES are solenoid-operated by the electric control system. Air pressure for each station is pre-set by the regulator. Bucking pressure controls motion of the ram head. Locating-pin cylinder checks ram motion at the proper position. Dial-station welder was developed by the Federal Machine and Welder Co., Warren, Ohio.



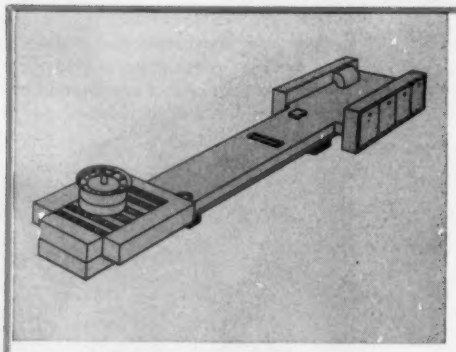
U 25 B

More power from



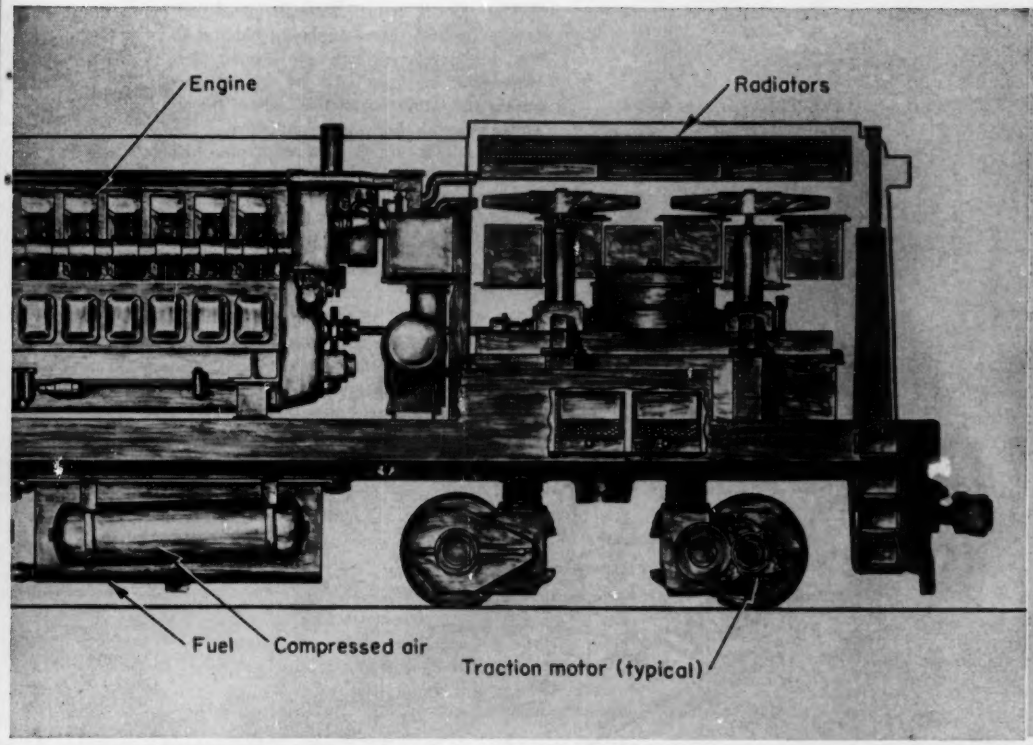
RUTHLESS SLASHING of unnecessary design features produced a simplified GE mainliner that combines ease of service with economy and added power. Designers worked from the following checklist:

- Eliminate unneeded features.
- Combine several functions in one part.
- Work for maximum reliability rather than maximum fuel savings.
- Use flow patterns for a logical layout of wiring and plumbing.
- Design for easy servicing.

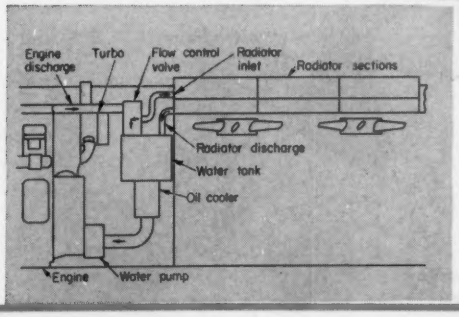


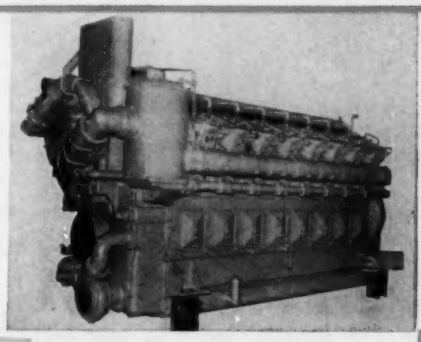
INTEGRATED AIR system shows how parts can be combined to simplify design. All air for combustion, cooling, and heating passes through one manifold. A single well-designed blower, geared to the engine, replaces the many separate motor blowers, generator blowers, and cab blowers used in former, or even contemporary, designs.

less machinery



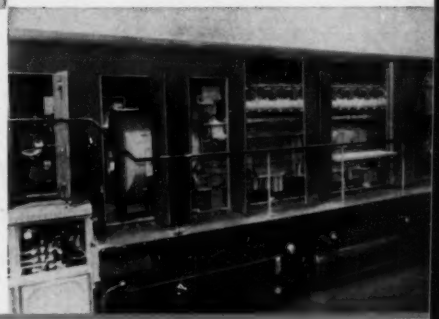
WATER-COOLING system uses bypass valves to keep radiators dry until they're needed. Then water enters at full flow instead of a trickle. Result—no freezeups, even in coldest weather.





POWERPLANT design uses multiple-function parts to reduce possibility of failure. Working parts of the engine are easily accessible for quick maintenance. Use of the biggest engine that could be fit into the locomotive has made a unit that will not be obsoleted by future powerplant designs, says GE.

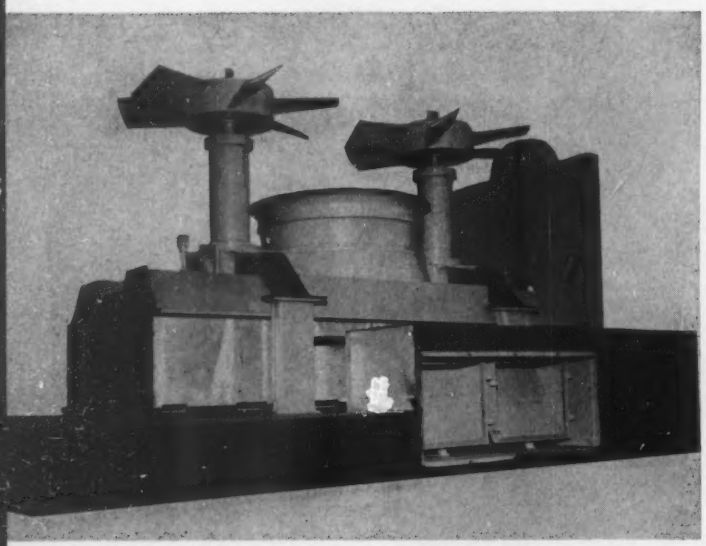
LAYOUT of the locomotive was kept simple. The floor is free of pipes and wires, and can be cleaned readily. Instead of an unsightly maze, plumbing and wiring is segregated in bundles for added safety and ease in servicing. Access doors make all machines in the locomotive readily available for inspection or repair.



More about these design problems on the following pages

Integrated Air Systems

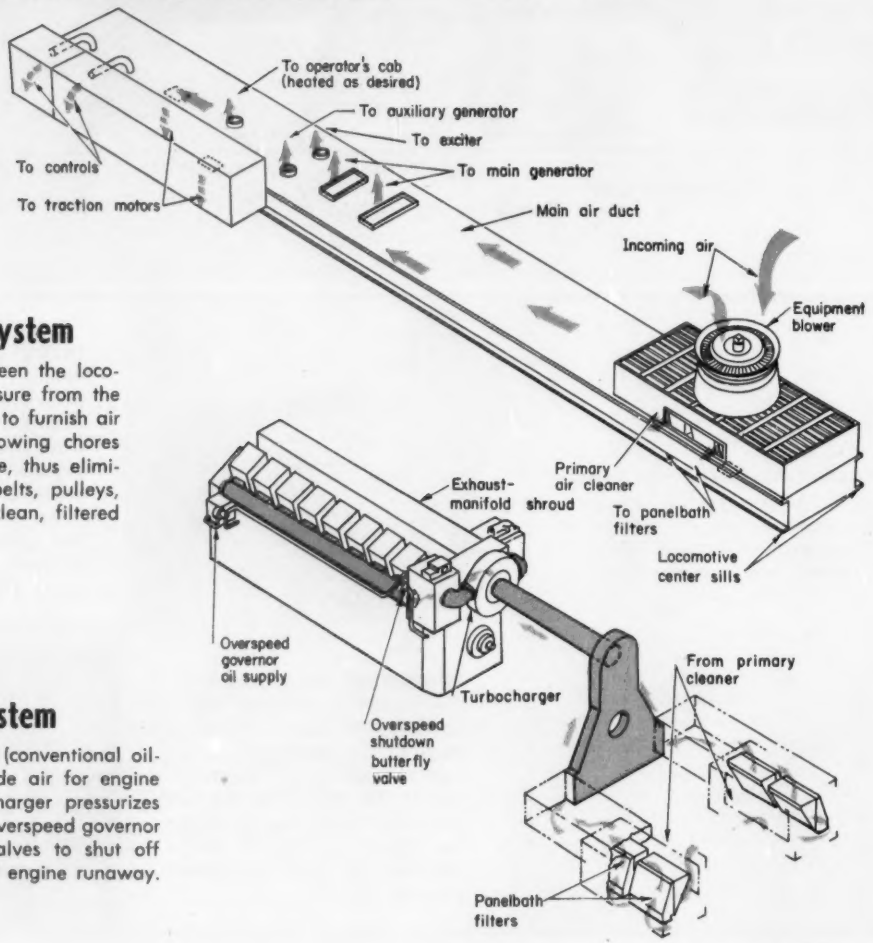
LOW-PRESSURE air for cooling motors and generators, heating the engineer's cab, and engine combustion is provided by a central plenum located between the main sills of the locomotive. The plenum is supplied from a single blower geared to the engine. Engine air is blown through panel-bath filters—oil-bath filters similar in function to the automobile oil-bath air cleaner, but rectangular in shape. Air for the radiators enters the same locomotive inlets, but is blown upward through the radiators as the plenum air is drawn downward into the filter units.



PLENUM BLOWER stands between two radiator blowers atop the primary air-cleaner case. Panel-bath filters are in the flanking boxes. Six engine radiators are set into the roof over the blowers.

Locomotive Air System

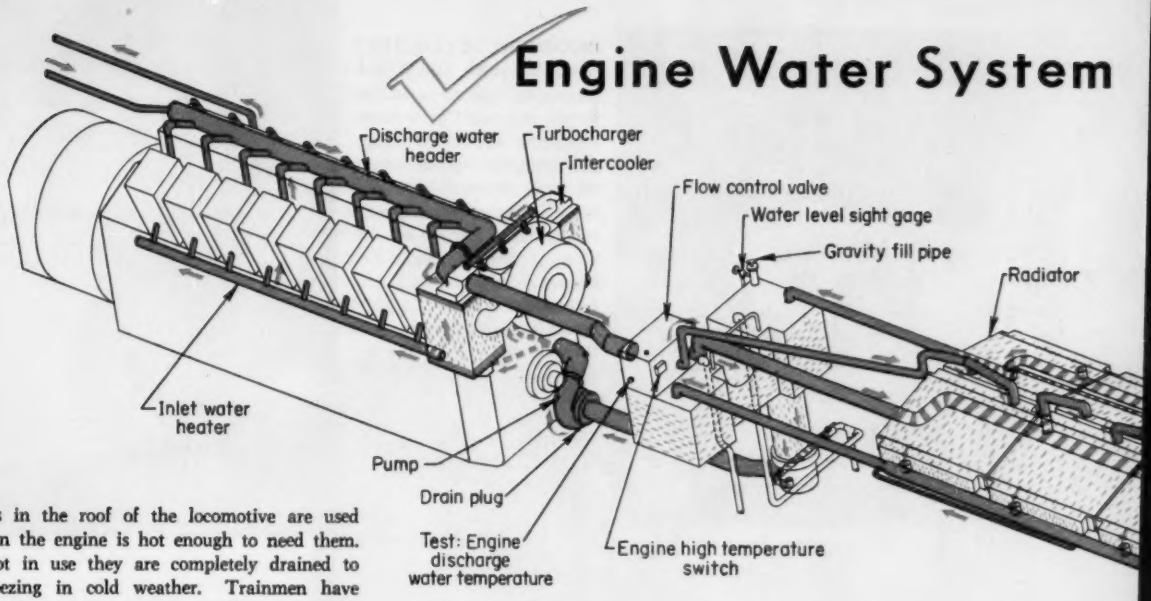
PLENUM is located between the locomotive center sills. Pressure from the input blower is sufficient to furnish air for all of the many blowing chores throughout the locomotive, thus eliminating blower motors, belts, pulleys, controls, and providing clean, filtered air for all demands.



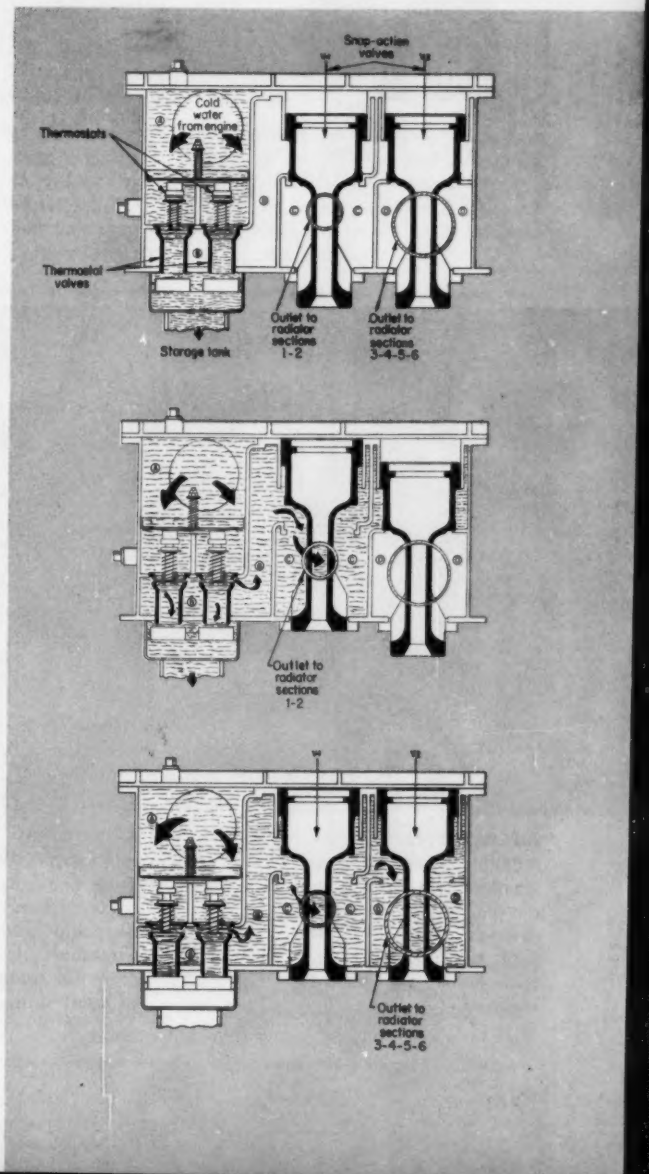
Engine Air System

PANEL-BATH FILTERS (conventional oil-bath cleaners) provide air for engine combustion. Turbocharger pressurizes intake manifolds. Overspeed governor operates butterfly valves to shut off air supply in case of engine runaway.

Engine Water System



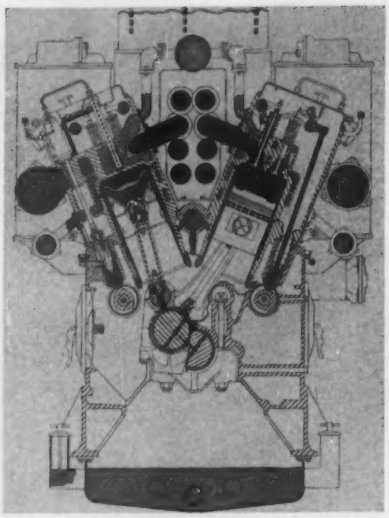
RADIATORS in the roof of the locomotive are used only when the engine is hot enough to need them. When not in use they are completely drained to avoid freezing in cold weather. Trainmen have discovered that during subzero weather a possible radiator freezing situation occurs when the thermostat opens enough to let water trickle very slowly into the radiator. Snap-action valves (below) solve this problem. Differential rates of cooling are provided by two-valves—one supplying two radiator sections and one supplying the other four. Intercoolers take heat from air leaving the turbocharger to increase engine efficiency.



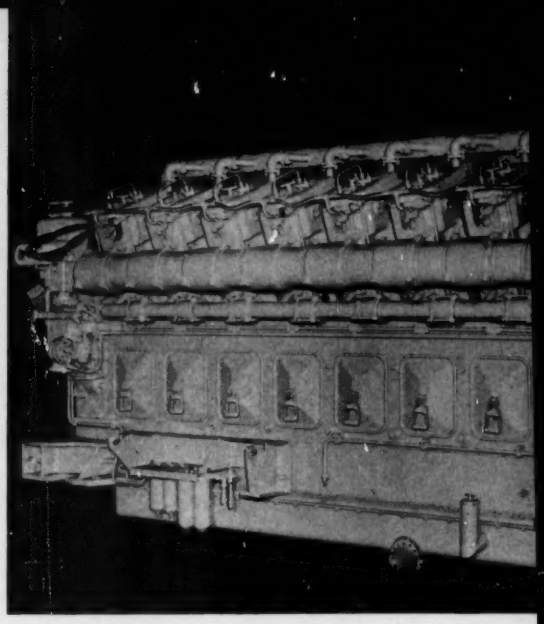
COLD WATER from the newly started engine is shunted by thermostat valves directly to the water-storage tank. Snap-action valves, V-1 and V-2, are both closed. Radiator lines are drained to the tank through hollow centers of snap-action valves.

As warmup progresses, thermostat valves open, filling compartment B with water. Pressure buildup to 4 psig opens snap-action valve V-1, supplying radiator sections 1 and 2 with water. Opening of V-1 relieves pressure, so V-2 remains closed. Remaining pressure in B operates on newly exposed seat of V-1 to hold it open.

High water temperature (high loads or high ambient temperature) opens thermostat valves wider, raising pressure in compartments B and C. At 4 psig V-2 snaps open. All radiators now operate until thermostat valves close, reducing pressure in B and C enough to allow V-1 and V-2 to drop back to closed positions.

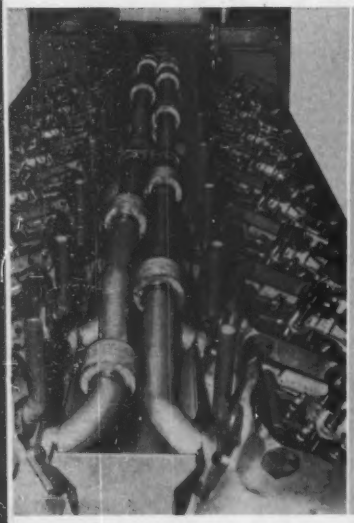


INDIVIDUAL CYLINDERS complete with heads are bolted to the frame. Liner forms one wall of a cooling-water jacket. It's supported by spline-like ridges on the internal cylinder wall. Air manifolds parallel cylinder banks on the side of the engine. Exhaust manifolds run between the banks. Exhaust gases eventually exit through the top of the locomotive.

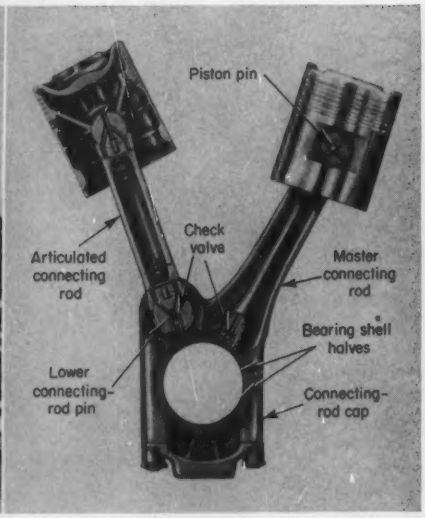


Powerplant

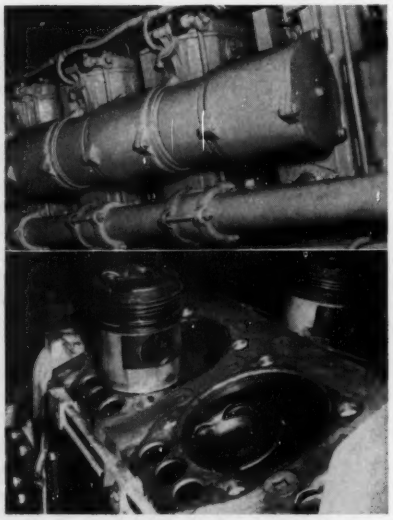
SPARTAN RESTRAINT in design appears most clearly in the engine for the U25B. External lines are kept to a minimum by using existing hollow members to conduct oil. Unnecessary links are eliminated. Symmetry is maintained to the extent that identical members can often be used in right



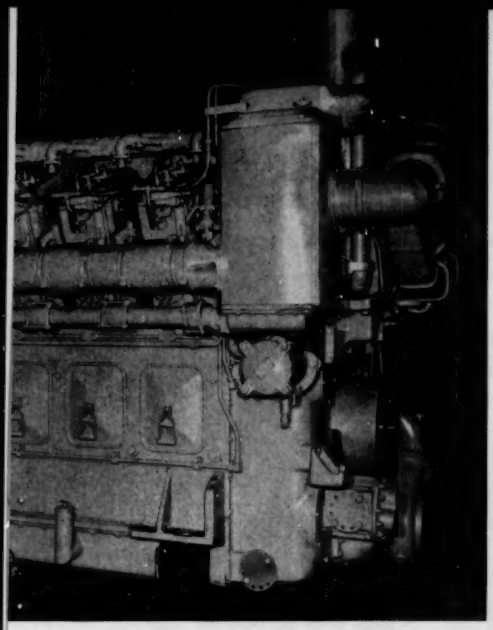
AIRCRAFT-TYPE exhaust manifolds use lightweight stainless steel tubing and dieform fittings rather than castings. Instead of slip joints and packing, expansion joints are bellows-enclosed.



ARTICULATED connecting rod allows two pistons to drive one crank pin. Increased bearing surface available prolongs critical crankshaft life and leaves room for added stiffening of crank arms.

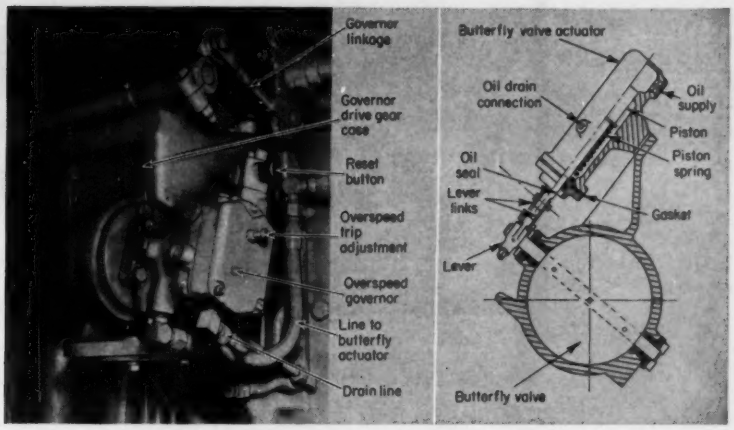


REMOVAL of cylinders is simplified by segmented air and water manifolds. Manifold sections ordinarily remain on the cylinder when it is removed. Pistons and crankcase are completely accessible with cylinders removed.



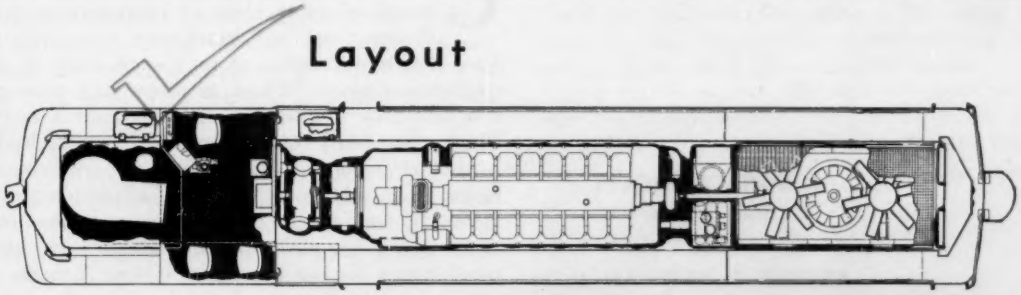
and left banks. Timing is easily done during assembly with a minimum of knowhow—it's a matter of lining up readily observed tram marks on the timing gear. Individual cylinders and heads are integral units each easily removed. This exposes pistons down to the wristpins.

DANGEROUS CRANKCASE explosions occur in two steps, say engine designers. A minor explosion in the oxygen-starved atmosphere of the crankcase blows out typical explosion-relief doors or plugs. Then air rushes in, providing oxygen for a blockbusting secondary explosion. Toggle latch in U25B's door is spring loaded. The door springs out under the force of a crankcase explosion to relieve pressure, but snaps back to block out air.

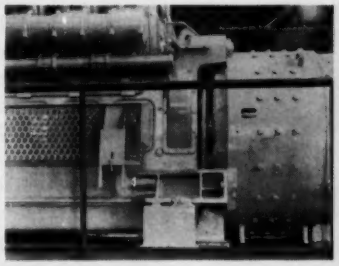


ADDED SAFETY comes from overspeed governor that controls air supply rather than fuel supply. Runaway due to leaking oil can't be stopped by cutting off fuel. Furthermore, the air control is a fail-safe device: In normal operation the governor maintains a head of oil against a piston to hold a butterfly valve open. Failure snaps the spring-loaded valve shut to starve the engine. Oil-exit hole assures immediate response of the valve.

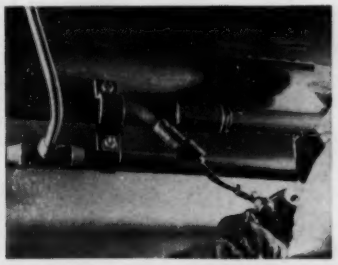
Layout



FUNCTIONAL layout of piping and wiring is no accident in the U25B. Engineers worked from flow charts to produce straight-through wiring and piping that followed routes established with a minimum of bends. Separation of longitudinal wiring and piping routes to opposite sides of the locomotive reduces hazards. Good housekeeping is a must on locomotives where rubbish and oil could combine to cause a disastrous fire.



DAYLIGHT under the engine shows accessibility of engine-room deck for cleaning and maintenance. A slight center crown permits it to drain to the outside.



FROZEN PIPE is thawed without danger to the electric wiring that is routed down the opposite side of the locomotive. Pipe lines are easily replaced because they are straight sections with a minimum of bends. For the same reason, it easy to trace piping and wiring.

AC MOTOR CONTROL-6

Characteristics and control of

Synchronous Motors

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Staff Engineer
and
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Application Engineer

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Cleveland, Ohio

CONSTANT-SPEED drives meet the special demands of many kinds of generators, pumps, blowers, and mill machinery. One type of drive that is well suited to such applications is the synchronous motor. Where ac power with constant line frequency is available, the synchronous motor offers a practically constant speed for varying loads.

Another important advantage of the synchronous motor is its inherently high and adjustable power factor. In fact, synchronous motors are often used to increase a low power factor produced in an electrical system by other types of motors. Benefits of unity or near-unity power factor for these other types of motors include increased efficiency and lower starting-current requirements.

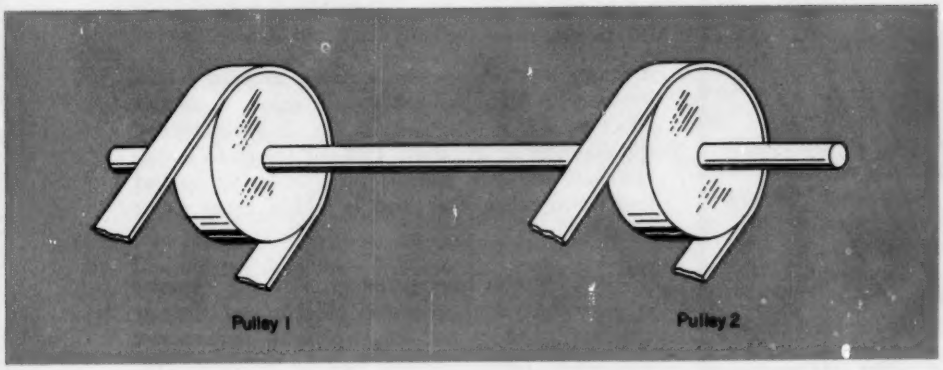
Other advantages offered by synchronous motors are pointed out in the following discussion of motor characteristics. Devices and control methods for providing synchronous operation are also covered in this article, the last in this series on ac motor control.

Motor Characteristics

The conventional synchronous motor has three basic windings—cage, stator, and field. The first two of these are similar to the windings of a squirrel-cage motor. The field winding, located physically on the rotor with the cage winding, is designed to carry direct current.

The stator winding is connected to the main ac

Fig. 1—Mechanical power-transmission analogy showing torque principles of a synchronous motor. The small-diameter shaft represents the magnetic coupling between the stator field and the rotor. Driven pulley 2 (rotor) lags behind driving pulley 1 (stator field) because of twist in the shaft, but the stable speeds of both rotating members remain the same.



power supply during both starting and running. The cage winding is used to accelerate the motor to approximately 95 per cent of synchronous speed. When this speed is attained, the field winding is energized from a dc supply. A strong, polarized rotor field is developed which "locks" into synchronism with the rotating stator field. Therefore, as long as ac input frequency is steady, motor speed remains constant regardless of normal load changes.

Torque: During the starting cycle, conventional speed-torque curves of induction motors apply. During the running cycle, however, the motor operates at a constant speed regardless of load-torque requirements. Although torque characteristics vary from one type of synchronous motor to another, a synchronous motor must be heavily overloaded before it is forced out of synchronism. "Pull-out torque" is the maximum torque that the motor can develop without being pulled out of synchronous speed. The numerical value of this torque is a function of the angular relationship between stator field and rotor.

The relationship of torque and synchronous operation can be visualized with a simple analogy. In Fig. 1, the two pulleys are keyed to a common shaft. Therefore, a force applied to pulley 1 compels pulley 2 to turn at the same rate of speed. However, forces of inertia or load acting on pulley 2 may cause it to lag behind pulley 1 because of torsional twist in the shaft. If the load on pulley 2 is increased, shaft twist will become greater and pulley 2 will lag further behind pulley 1. No matter how great the lag, however, the stable speeds of both pulleys remain equal unless the shaft breaks.

In a similar manner, the rotor of a synchronous motor is locked in with the rotating stator field. As with lagging pulley 2, the rotor lags behind the stator field because of rotor inertia, external

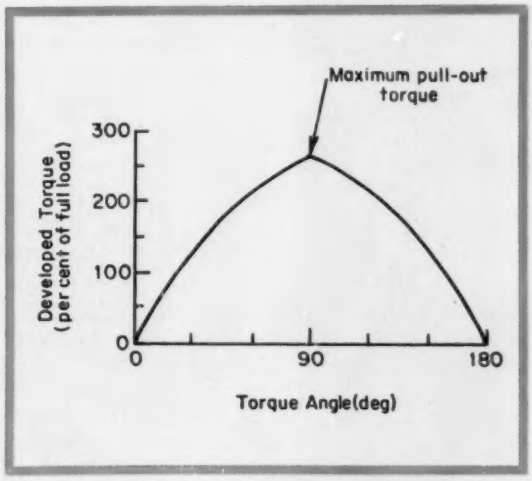


Fig. 2—Typical curve of developed torque versus torque angle for a synchronous motor.

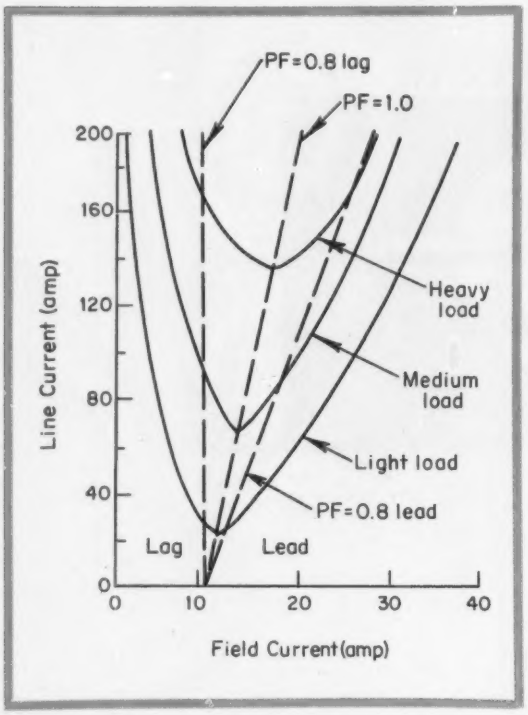


Fig. 3—Characteristic power factor and load curves for a synchronous motor.

load, or both. As the amount of lag or torque angle increases with increasing load, developed torque also increases up to the point of maximum pull-out torque, Fig. 2. If the coupling angle increases further, pull-out torque decreases. Although the maximum torque-coupling point remains constant for a given motor (approximately 90 deg in Fig. 2), the value of pull-out torque is variable and depends on:

1. Size and type of load.
2. Ac line voltage.
3. Dc field strength.

A strong dc field provides a strong coupling which produces a high pull-out torque value. A similar effect would be obtained in Fig. 1 by increasing the diameter of the shaft. Pull-out torque of a synchronous motor is reduced by a suddenly applied load, even when that load is within rated motor capacity.

Speed: A synchronous motor normally operates at a constant average speed. Usually, an absolute constant speed is not an imperative requirement and minor speed variations can be tolerated. Synchronous motor speed variations are inherently small, especially in the larger motor sizes.

Load variations, however, can cause fluctuations above and below synchronous speed. Also, every motor has a frequency of oscillation which causes natural speed variations. In pendulum fashion, a speed increase is followed by a speed decrease of equal magnitude so that variations from synchronous speed always balance out. This characteristic is called hunting. If the frequency of load fluctuations and natural motor oscillations are nearly the same in timing, the total deviation that results can be-

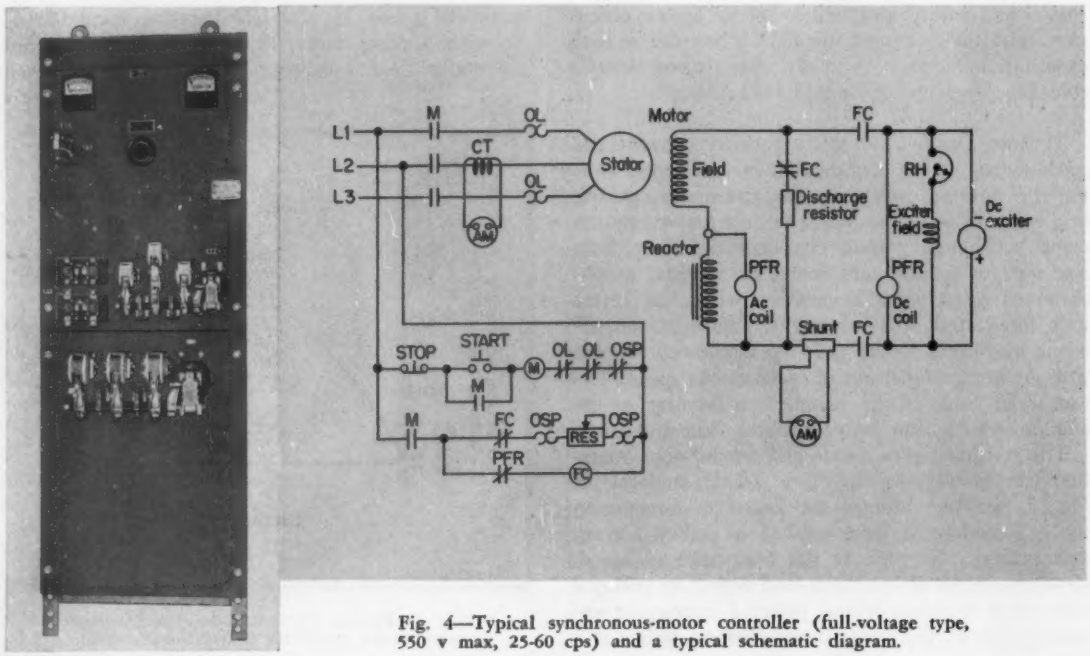


Fig. 4—Typical synchronous-motor controller (full-voltage type, 550 v max, 25-60 cps) and a typical schematic diagram.

come great enough to force the motor out of synchronism. Design improvements, however, have minimized hunting tendencies in synchronous motors.

Direct-coupled synchronous motors are better suited for low-speed operations (those requiring less than 500 rpm) than squirrel-cage motors. In such applications, both power factor and efficiency of synchronous motors remain high. Of course, efficiency of squirrel-cage motors can be improved by using higher-speed motors with gear reducers, but space requirements and cost also increase.

Power Factor: Adjusting the dc field of a synchronous motor changes its power factor. When the field is overexcited, the motor draws a leading current; when underexcited or weakened, the motor draws a lagging current.

Fig. 3 combines synchronous-motor load curves with power-factor curves. At normal field excitation, line current drops to a minimum and power factor becomes unity. The unity power-factor curve always passes through the low points of the load curves.

Synchronous drives, with leading power factor, are often used to balance and improve the power factor of a plant's electrical system. Because the rate charged for power decreases as power factor of an over-all system approaches unity, synchronous motors can provide a significant economic byproduct. Induction motors are usually the main cause of reduced power factors.

Efficiency: Synchronous motors operate at high efficiencies—even higher than can be obtained with induction motors. Where large amounts of power are involved, the savings in cost of electric power can be substantial. Efficiency of a synchronous motor depends on horsepower, power factor, and speed. As horsepower approaches its rated value and power factor approaches unity, efficiency increases. Efficiency is also highest when rotor slip is at a minimum.

Flexibility: Synchronous-motor design and performance can be readily adapted to a variety of conditions. Because the cage winding is effective only during the starting period, the rotor bars can be designed with high-resistance characteristics to provide high starting torque. Such a motor has low slip and high efficiency at full speed. Also, a wound-rotor winding with its associated benefits[5] can be used for starting purposes.

Multispeed operation is possible with a synchronous drive if the motor is built with multiple stator windings.[4] Synchronous motors can also be operated on reduced-voltage starting. The starting current for a low-speed (under 500 rpm) synchronous motor at full-voltage starting, however, may be only about $3\frac{1}{2}$ times full-load current (as compared to approximately six times for a squirrel-cage motor).

Disadvantages: Characteristics of synchronous motors that may be cause for concern when considering an application are:

1. Need for a dc power supply.
2. Possible loss of synchronism as a result of power-system disturbances and hunting.
3. Generally greater initial expense.

Loss of synchronism today is of relatively minor importance because of steady frequency control by power companies and improved motor design and control techniques. The cost factor, too, becomes less important when the uneconomic aspects of lagging power-factor operation are considered.

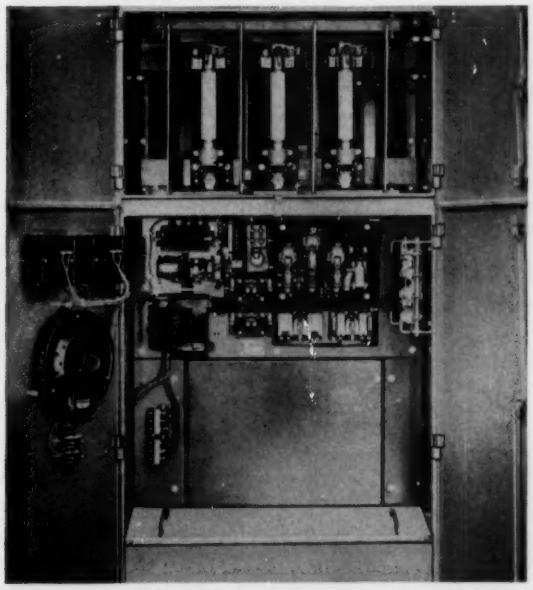


Fig. 5—Typical reduced-voltage synchronous-motor controller. Features are: Primary reactor for starting, high-interrupting-capacity fuses, oil-immersed main contactors, 4600 v max, 3 phase, 60 cps.

Motor Control

A basic controller for a synchronous motor, Fig. 4, incorporates four components:

1. A three-pole starter for the ac stator circuit.
2. A contactor for the dc field circuit.
3. An automatic synchronizing device to control the dc field contactor.
4. A cage-winding protective relay to open the ac circuit if the motor operates too long without sychronizing.

Of course, additional components are added as starting, stopping, and control requirements become more complex. For example, the controller shown in Fig. 5 includes the control components required for reduced-voltage starting.[3]

Starting: Because a synchronous motor requires ac power during both starting and running, the main contactor is always closed when the motor is operating. The dc winding of the rotor is energized by the field contactor as the motor approaches synchronous speed. Two normally open poles on the field contactor make the connection for dc excitation,

[5]References are tabulated at end of article.

and one normally closed pole permits dissipation of induced field current (through a resistor) during any period of nonsynchronous operation.

Synchronizing: For smooth synchronization, two conditions determine the instant that the dc field is energized:

1. The rotor must be turning at the proper speed—usually 93 to 98 per cent of synchronous speed.
2. The rotor poles must be lagging slightly behind stator poles of opposite polarity.

Any of several different synchronizing devices can be used to apply dc to the rotor field. Typical of these devices is the relay system identified as PFR, which is included in the starter circuit of Fig. 4. Its function can be illustrated with an explanation of the circuit.

Pressing the *start* button closes main contactor M and connects the motor stator to the ac line. The motor accelerates as an induction motor. An induced alternating current flows in the motor field circuit with a frequency proportional to the slip of the motor. (The frequency of the induced field current is the same as line frequency when the motor is at standstill and approaches zero as the rotor nears synchronous speed.)

At first induced alternating current passes through the PFR ac coil so that both the ac and the dc coils of the PFR synchronizing relay are energized. These two coils open the PFR contact at the instant main contactor M closes and prevent field contactor coil FC from being operated. Therefore, direct current is not initially applied to the motor field.

As the motor speeds up, frequency of the induced current is reduced proportionately. Because the PFR ac coil is in parallel with a reactor, the declining frequency permits the induced current to begin passing through the reactor instead of through the coil. When the motor reaches the proper speed, magnetic force of the PFR ac coil is so weak that its contacts return to their normally closed position. Then, field contactor FC is energized, and its two normally open contacts close and apply direct current to the rotor field.

Thus, the synchronizing relay responds to declining frequency in the field-discharge circuit so that dc excitation is applied at the correct motor speed. But this operation satisfies only the first condition for best synchronization. In addition, the rotor position must be properly related to the polarity of the stator field. If excitation is applied to the dc field during the first half of a negative wave of the induced current, this second condition will be met.

The polarized type of relay, Fig. 6*a*, is so designed that its armature drops out when the magnetic fluxes of the two coils have a definite relative strength and are in opposition. Induced alternating current is the variable which determines when the armature drops out to close the relay contact, Fig. 6*b*.

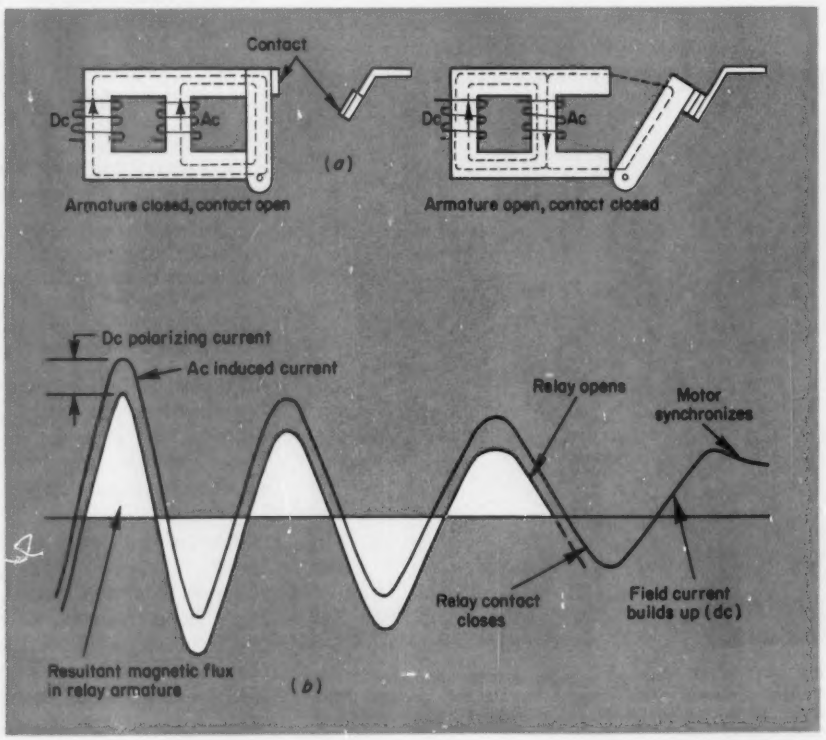


Fig. 6—Typical synchronizing relay. Magnetic flux paths, *a*, are indicated for closed and open armature positions. Induced ac wave, *b*, controls operation of relay.

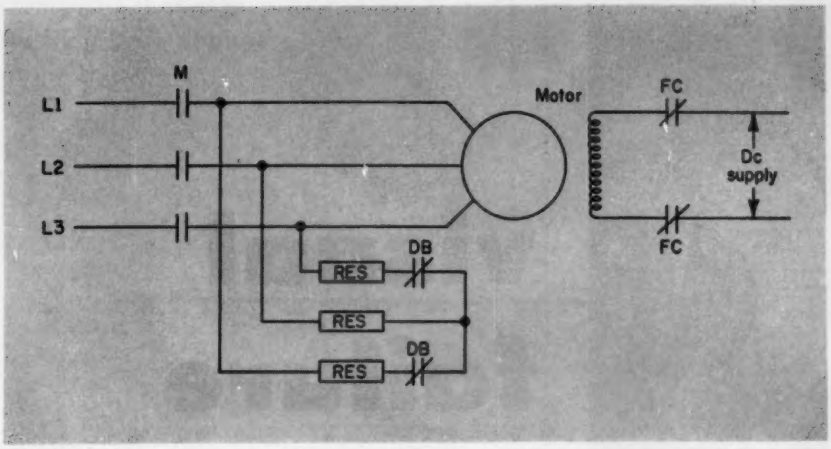


Fig. 7 — Power-circuit schematic diagram for dynamic braking of a synchronous motor. Contacts are shown in the required positions for braking.

Magnetic flux from the dc coil produces a resultant flux wave that is unsymmetrical with relation to the zero line. As the current wave stretches out and loses magnitude, the relay armature opens during one of the small positive (upper) loops. The time lag of mechanical operation delays contact closure—and application of dc excitation—until the first half of the negative wave. The direct current in the field then builds up properly for smooth synchronization.

If a momentary overload or voltage dip occurs, the motor may be forced out of synchronization. As soon as the motor falls "out of step," induced current in the PFR ac coil closes the relay and opens its contact. De-energization of the field contactor immediately removes dc excitation. When line voltage returns to normal or the overload is removed so that the motor can develop the necessary pull-in torque, synchronous operation is automatically restored. In some cases resynchronization may not be desirable from a safety standpoint—if so, the controller circuit must be designed to disconnect power from the stator.

Protecting: The out-of-step protective relay for the cage winding is usually a conventional thermal-overload device. Such a device, identified as OSP, Fig. 4, is energized whenever the motor is running without rotor field excitation. If, during a start, the motor does not sychronize within a given period of time (usually 15 to 20 sec), the OSP relay operates and opens the main contactor.

If the motor pulls out of step while it is running, the OSP relay disconnects the motor unless resynchronization occurs within the specified time. This protection is necessary because the cage winding has limited thermal capacity and will overheat in a short time at subsynchronous speeds.

If a synchronous motor is started, then immediately stopped and restarted, the OSP relay operates with a shorter time delay than normal. This happens because its thermal element has not had sufficient time to cool to its original (ambient) temperature between starts. This feature is desirable because the motor also needs time to cool. Without such protection, the cage winding would overheat if starts were attempted at too close intervals.

Stopping: Synchronous motors can be stopped quickly by methods similar to those used with induction motors.[2] Plug stopping requires a reversing control. Dynamic braking requires a set of braking resistors and a contactor to connect the resistors across the motor stator, Fig. 7. The dc field winding remains excited. The motor then functions as a generator and dissipates the inertial energy through a resistor bank. The degree of braking can be varied by changing resistance values.

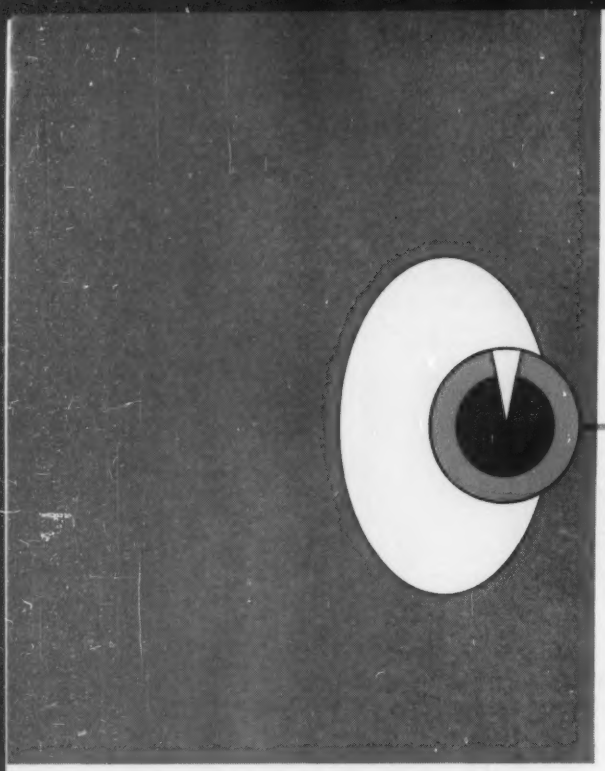
References

This article is the sixth and concluding part in a series by J. Ronald Wickey and Arthur S. Newman Jr. on ac motor control. Previous articles and issues of Machine Design in which they appeared are:

1. Squirrel-Cage Motors ..... December 22, 1960
2. Across-the-Line Starting ..... January 5, 1961
3. Reduced-Voltage Starting ..... January 19, 1961
4. Starting Multispeed Motors ..... February 2, 1961
5. Wound-Rotor Motors ..... February 16, 1961

They say . . .

"It is true that man, in the development of engineering, has used the wheel and rotary motion to an ever-increasing extent. It is perhaps salutary to remember that Nature has quite an opposite preference, reciprocating motion predominating. In fact it would appear that in terrestrial affairs Mother Nature abhors rotary motion. The greatest concession which Nature makes to rotary motion is in swinging to and fro in an arc, and spherical joints are common. The only exception to all this reciprocating motion occurs at the two extremes of the scale of creation, in astronomy where the stars are substantially all spherical in shape, describing circular or elliptical orbits, and similarly in the near infinitely small we have the atoms and their associated electrons."—H. Desmond Carter, *President, Institution of Mechanical Engineers, London, England*



visual failure indicators

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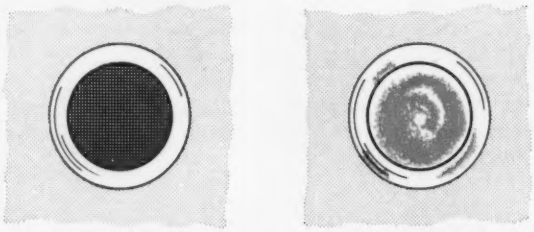
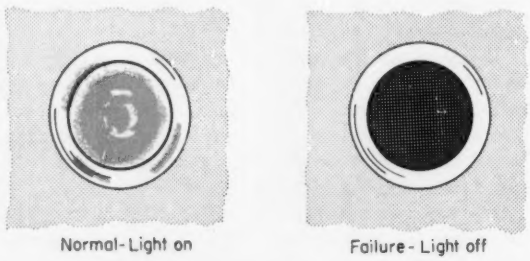
EARLY WARNING of equipment failure or malfunction can prevent expensive shutdowns and damage to both men and machines. To this end, here are a number of ways to signal equipment operators. Basic visual methods are change of color, change of motion, change of position, and combinations of these changes. Selection and application of visual indicators are guided by these factors:

1. Location of equipment with respect to operator. Is equipment operated directly or remotely?
2. Degree of equipment damage that will result if failure is not detected and corrected.
3. Possibility of injury to operating personnel.
4. Operators' or attendents' perceptiveness and ability to respond.
5. Frequency of equipment operation check.

Color change

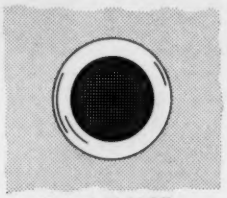


Failure only in lamp could prevent light signal from coming on.



Signal fails safe. That is, absence of light attracts attention whether failure is in lamp or equipment.

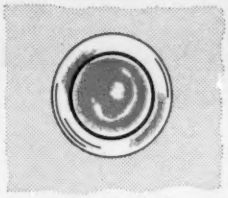
Flashing color change



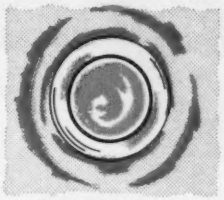
Normal-Light Off

Failure-Blinking Light

Failure only in lamp could prevent light signal from coming on.



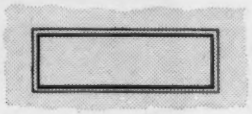
Normal-Light On



Failure-Blinking Light

Signal fails safe. That is, absence of light attracts attention whether failure is in lamp or equipment.

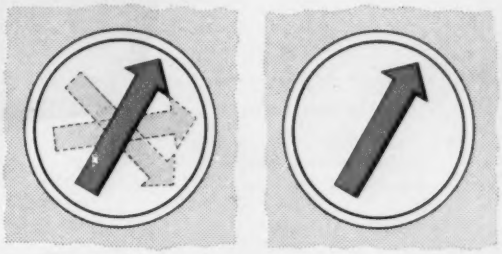
Color appearance



Normal Failure

Normally, translucent cover blends with panel. Failure indication, in vivid color, shows through.

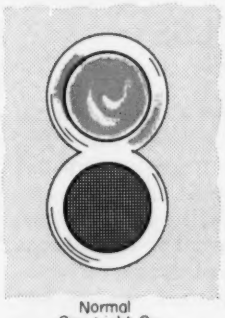
Motion change



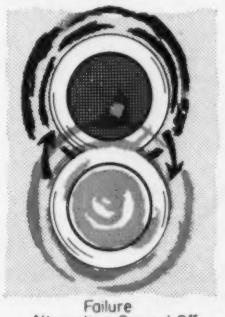
Normal Failure

Normally, pointer oscillates or cycles at easily noticed frequency. When slowed or stopped, pointer indicates failure.

Combined color and position change



Normal
One Light On

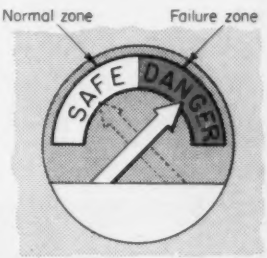


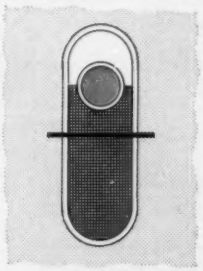
Failure
Alternating On and Off

Second light adds movement to failure indicator, also provides safety factor if one lamp fails.

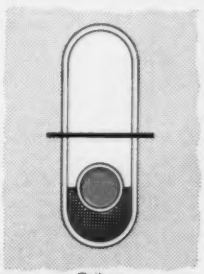
Position change

Meter-type indicator may need close observation.



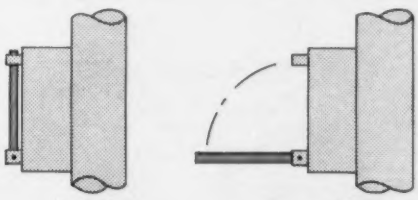


Normal



Failure

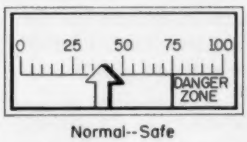
Floating-ball indicator should not be used on equipment in which certain motions, unrelated to failure, could change the fluid level.



Normal Failure

Good for installations where indicator is easily visible but hard to reach.

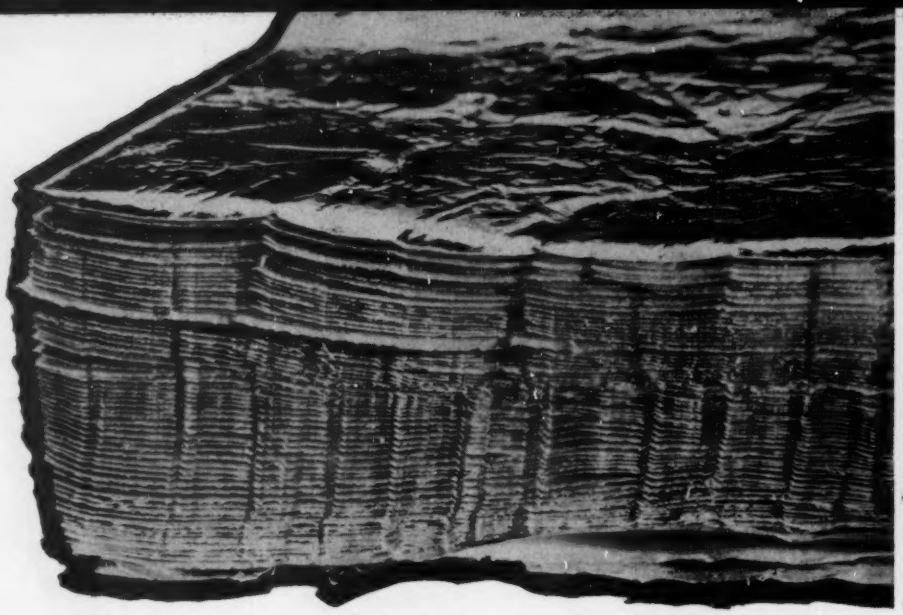
Illumination color change



Normal--Safe

Failure--Danger

Background illumination changes color when pointer enters danger zone. Pointer itself is position-type indicator.



Layers of thin aluminum foil separated by special glass-fiber paper comprise Linde SI superinsulation, with density of 4.7 lb per cu ft. When used at 0.1 mu absolute pressure, insulating efficiency is 30 times that of evacuated perlite.

Superinsulations

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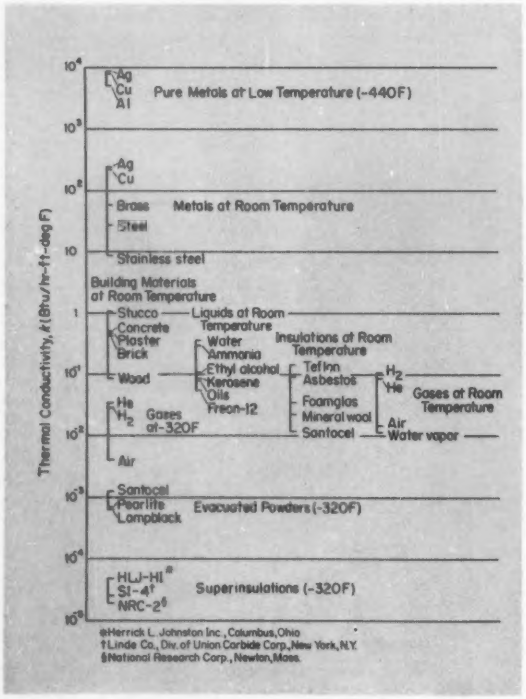


Fig. 1—Ranges of thermal conductivities for various materials. Data are from References 1, 2, 3, and 4.

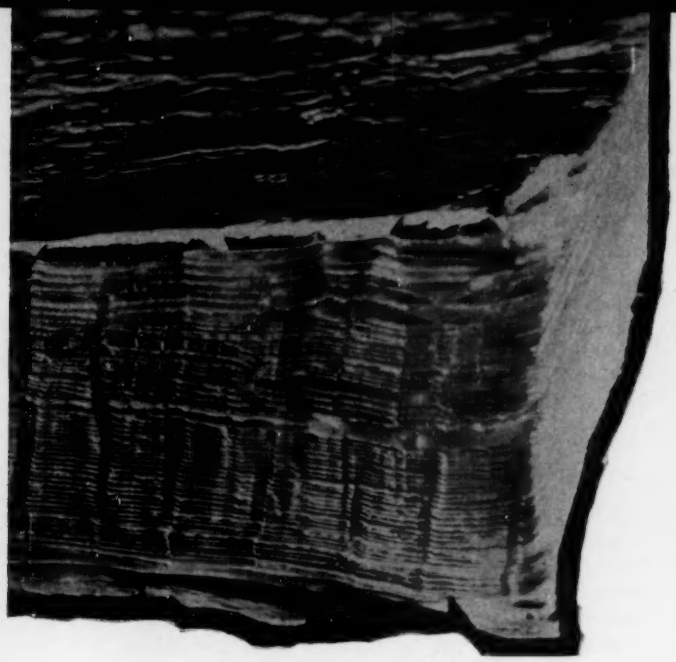
NEW, laminar-type materials meet the current demands for high-efficiency insulation in extremely low temperature applications. The thermal-conductivity range of these superinsulations is 1/10 to 1/50 that of the more common low-temperature insulations, Fig. 1. This article describes the superinsulations and their properties and discusses their past, present, and future roles in the field of cryogenic design.

Materials

Generally, a superinsulation consists of a multilayer sandwich of a bright, highly reflective substance separated by a spacer material of low thermal conductivity. The sandwich is enclosed between the walls of a double-wall container, and the insulation chamber is then evacuated to a pressure of less than 1 mu Hg (0.00002 psia).

Materials in common use as reflective shields are aluminized Mylar and aluminum foil, ranging in thickness from 0.0002 to 0.005 in. Other materials being considered are foils of tin, stainless steel, gold, copper, and cadmium.

Materials used to separate the reflective surfaces



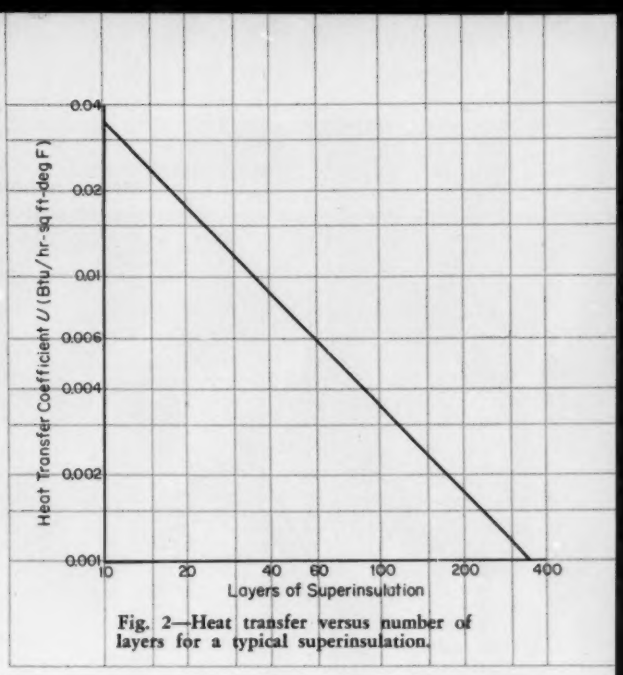


Fig. 2—Heat transfer versus number of layers for a typical superinsulation.

. . . for near absolute-zero temperatures

include Fiberglas paper or Dexter paper, Fiberglas fiber mat, Fiberglas fabric, nylon net, opacified powders, and polystyrene glasswool.

Heat Transfer

The rate of heat transfer through a superinsulation is extremely low because all three means of heat transfer—radiation, gaseous conduction, and solid conduction—are reduced to a minimum in the composite insulation.

Radiation: Heat radiated from a hot to a cold surface is directly proportional to the emissivity of the surfaces and inversely proportional to the number of intermediate surfaces or shields. Thus, a large number of shields of a material, such as aluminum with an emissivity of 0.05 (95 per cent of radiant heat is reflected), is a very effective block to radiant heat.

Gas Conduction: Because the spacing between each layer of insulation is smaller than the mean free path of the gas molecules, the heat conducted through the residual gas is directly proportional to the gas pressure. Therefore, at an absolute pressure of approximately 0.1 mu, gaseous conduction through superinsulations is so small that it is negligible.

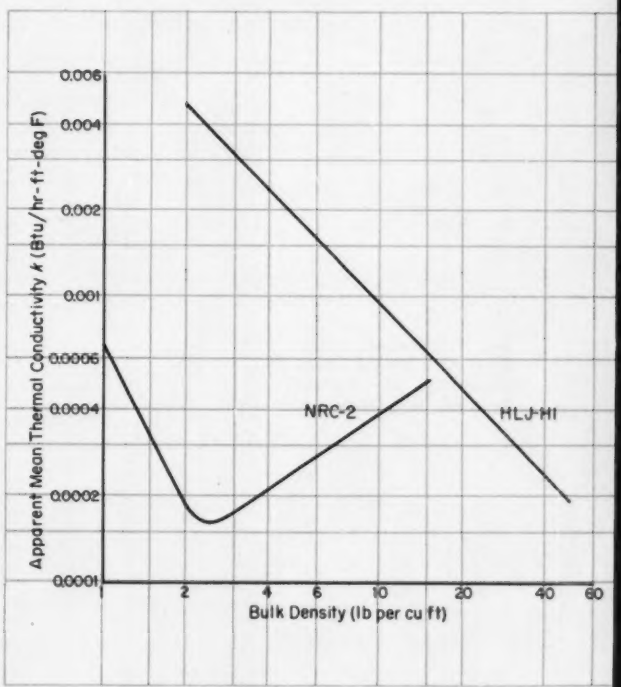


Fig. 3—Effect of density on thermal conductivity of superinsulations.

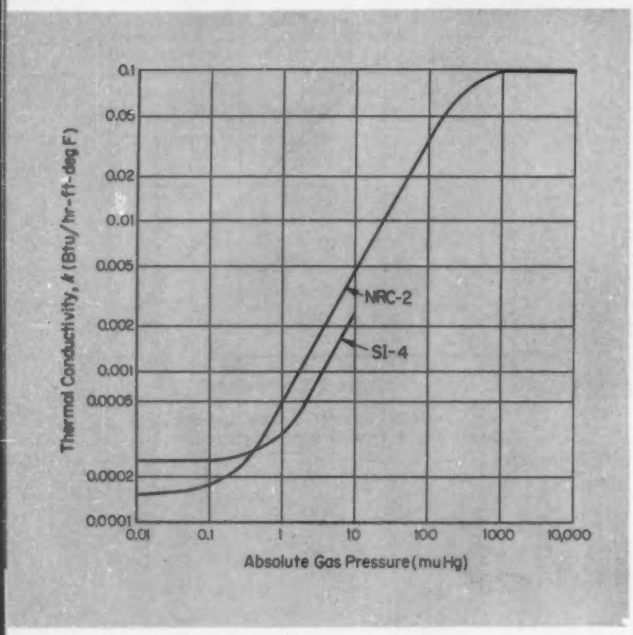


Fig. 4—Effect of gas pressure on thermal conductivity of superinsulations.

Solid Conduction: Heat conducted through the spacer material is directly proportional to the thermal conductivity of the material and to the resistance to heat flow at the areas of contact between particles. Factors that contribute to the low heat conduction through the spacer materials in superinsulations are: 1. Low conductivity of materials. 2. Size and geometry of fibers. 3. Discontinuity of fibers.

Density

Bulk density of a superinsulation depends upon a number of factors: 1. Thickness of the reflective foil. 2. Type of spacer material. 3. Packing density (layers per inch of thickness). Typical values of bulk density for commercial superinsulations range from 2 to 20 lb per cu ft, with packing densities ranging from 40 to 80 layers per inch. For a given heat-transfer rate, volume and weight requirements for superinsulations are much less than those for conventional insulations.

Thermal Conductivity Tests

Various combinations of reflective shields and insulating spacers have been tested for thermal con-

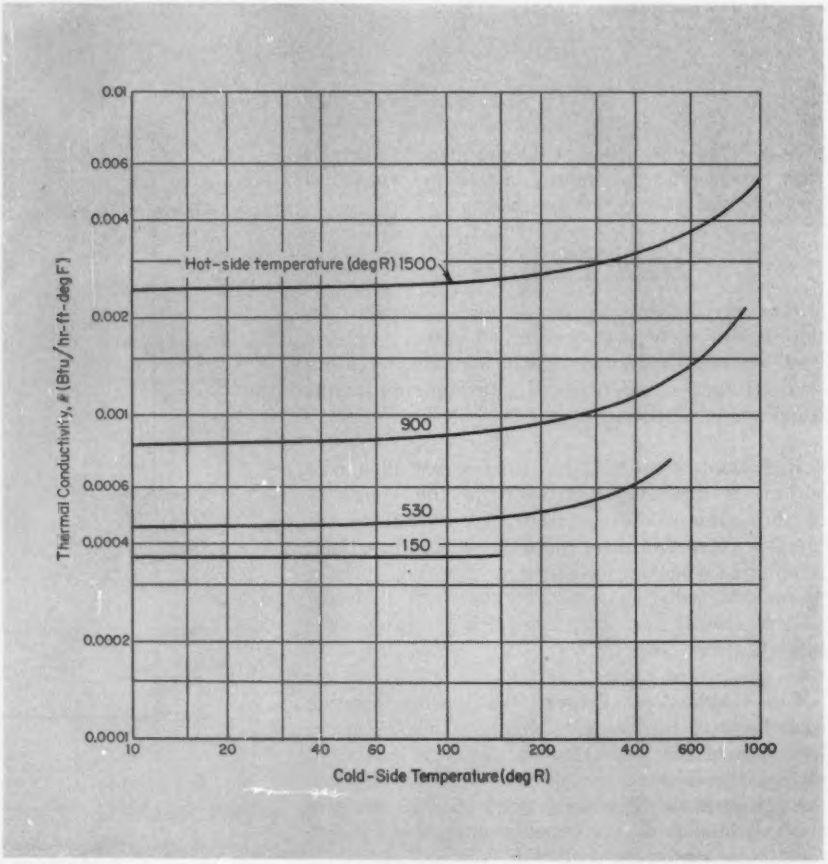


Fig. 5—Thermal conductivity of a typical superinsulation at various boundary temperatures.

History and Development of Superinsulation

Although superinsulations have been developed only recently, the methods by which they reduce heat transfer are not fundamentally new. James Dewar, the first to liquefy hydrogen, was also the first to use an evacuated space as an insulation. In 1898, he invented the Dewar vessel, a double-wall glass container with a vacuum in the space between the highly silvered walls.

By applying principles of the kinetic theory of gases, Smoluchowski demonstrated in 1910 that if the space between particles of insulation could be made smaller than the mean free path of the gas molecules, the insulation would be more effective than the gas itself.[8] For example, for air at 70 F and 0.1 mm Hg absolute pressure, the mean free path is approximately 0.02 in. Thus, with insulation spacing of only 50 layers per inch, the distance between layers is of the order of the mean free path at this degree of vacuum. At pressures of 0.1 mu Hg (1000 mu = 1 mm), commonly used with the superinsulations, the mean free path of air is approximately 20 in.

With the combination of high vacuum and multilayer reflective shields, a fairly low heat-transfer vessel can be constructed without any spacer material. Several liquid helium and liquid-hydrogen tanks were insulated in this manner in the 1940's and early 1950's. The shields were usually supported by small metallic braces to the walls of the container—a costly and time-consuming construction. Shields were limited to 4 or 5 per inch because of inaccuracies in forming and assembly. If the shields touched one another at any point, their effectiveness was seriously reduced.

In 1951, Peterson, at the University of Lund in Sweden, found that alternate layers of thin, polished aluminum foil and fine glass-wool spacers, spirally wound around a cylindrical vessel and contained in a vacuum, showed remarkable insulating qualities.[9] This was the first known instance of a superinsulation applied to a cryogenic storage vessel. At the time, the announcement of his discovery did not arouse much interest because powder insulations such as Santocel (a silica aerogel) and perlite (another silica powder) were less expensive and seemed adequate for most purposes.

The demands of the missile industry, however, called for more efficient insulations. To meet these demands, several companies launched research programs to develop more efficient insulations than the evacuated-powder types. At first, opacifying the powders with aluminum or copper flakes was tried. However, after some study, it became apparent that randomly dispersed reflective flakes were not the most effective barriers to radiation because of voids between flakes. Furthermore, too large a concentration of metallic flakes could bring about a "thermal short circuit," which would greatly increase heat transfer by conduction.

Research was then directed toward laminated insulations similar to the one suggested by Peterson, in which the continuous radiation shields were separated by a low-conductivity material. Previously it was thought that radiation shields had to be completely separated by a vacuum to be effective and that the reflective characteristics of the shields would be seriously impaired by contact with an insulating filler. Research showed that neither of these concepts was true. The radiation shields could be separated by a filler material only a few thousandths of an inch thick without impairing the radiation-barrier qualities of the shield. In fact, the composite insulation could be used as a means of elastically supporting the inner container within the outer one in a double-wall vessel.

Table 1—Characteristics of Superinsulations

Materials		Density	Reflectors	Cold Surface	Conductivity, k	
Reflector	Insulator	(lb/cu ft)	per Inch	Temp. (R)	(Btu/hr-ft-deg F)	Reference
Aluminized Mylar	Fiberglas AA, 0.02 in.	5.0	40	140	27.5×10^{-5}	5
		..	65	140	8.8	6
	Dexter paper, 0.008 in.	3.8	..	140	18.5	7
		3.8	..	37	13.9	7
	Perlite	..	56	140	4.3	6
Aluminum foil, 0.002 in.	Powder, 0.02 in. (silica carbon)	24.0	40	140	29.4×10^{-5}	5
	Fiberglas AA, 0.02 in.	16.0	40	140	18.6	5
	Fiberglas, 0.002 in.	20.0	40	140	8.0	5
Aluminum foil, 0.001 in.	Fiberglas, 0.001 in.	13.0	60	140	14.7×10^{-5}	1
	Fiberglas, 0.005 in.	19.0	60	140	4.9	1
Aluminum foil, 0.0005 in.	Dexter paper, 0.008 in.	6.9	37	140	4.3×10^{-5}	7
	Dexter paper, 0.005 in.	7.0	50	140	3.0	7
		7.0	50	37	2.4	7
	Fiberglass AA, 0.02 in.	..	52	140	13.3	7
	Fiberglas mat	..	78	140	1.9	2
		2.5	15	162	11.0	4
		4.7	60	162	2.5	4
Aluminum foil, 0.00025 in.	Dexter paper, 0.008 in.	..	52	140	25.8×10^{-5}	5
		7.5	55	140	3.2	7
		7.5	55	37	2.3	7
		7.5	48	140	6.4	7
		5.9	52	140	8.7	7
		..	53	140	4.0	6

ductivity by several investigators. Results of these tests are shown in Table 1.

For ten or more layers of insulation, heat-transfer coefficient U varies inversely with the number of layers, Fig. 2.[1] Within certain limits, thermal conductivity k for one insulation was found to vary inversely with bulk density; another insulation showed a distinct minimum in the thermal-conductivity curve, Fig. 3.[1,2] Had the tests on HLJ-HI insulation been extended to higher bulk densities, no doubt a minimum value would have been exhibited in this curve also.

A curve showing variation of thermal conductivity with gas pressure within superinsulation, Fig. 4,[2,4] is similar to those of the powder insulations. However, conductivity increases sharply at approximately 0.1 to 0.5 mu Hg for superinsulations as compared with 10 mu Hg for the powder insulations. Molecular conduction is directly proportional to the absolute pressure of the gas as long as the spacing of the insulation layers is smaller than the mean free path of the gas. As the mean free path becomes less than the layer spacing (at higher pressures), thermal conductivity increases rapidly.

Applications

Superinsulations are used currently to insulate cryogenic liquid-storage vessels up to capacities of 28,000 gal. In this application the superinsulation is so effective that liquid hydrogen can be stored for one year at −423 F in a 26,000-gal tank with an evaporation loss of less than 10 per cent. With the powder insulations, 10 per cent of the liquid would evaporate in approximately 20 days.

Superinsulations are mechanically stable. They withstand the shock and vibration conditions of applications such as cryogenic fluid-storage trailers.

If the problem of maintaining a high vacuum within the insulation without the use of heavy enclosures can be solved, superinsulations would be ideal for insulating fuel tanks on satellite launchers.

It is believed that the maximum operating temperature of superinsulation is at least 1000 F. This limit could be extended considerably if stainless steel were used instead of aluminum and if quartz fibers were used in the place of glass fibers. Fig. 5[1] shows calculated thermal conductivities of a typical superinsulation at various boundary temperatures.

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to Dr. H. L. Johnston, President, Herrick L. Johnston Inc., for permission to use the graphs from Reference 1 in this article.

REFERENCES

The author wishes to express his sincere appreciation to Dr. Herrick L. Johnston Inc., Columbus, Ohio, September, 1960 (unpublished report).

2. M. P. Hnilicka—"Engineering Aspects of Heat Transfer in Multilayer Reflective Insulation and Performance of NRC Insulation," 1959 *Cryogenic Engineering Conference Proceedings*, Plenum Press Inc., New York, 1960, p. 199.
3. W. H. McAdams—*Heat Transmission, Third Edition*, McGraw-Hill Book Co. Inc., New York, 1954, pp. 445-458.
4. P. M. Riede and D. I-J. Wang—"Characteristics and Applications of Some Superinsulations," 1959 *Cryogenic Engineering Conference Proceedings*, Plenum Press Inc., New York, 1960, p. 209.
5. I. A. Black, A. A. Fowle, and P. E. Glaser—"Development of High-Efficiency Insulation," 1959 *Cryogenic Engineering Conference Proceedings*, Plenum Press Inc., New York, 1960, p. 181.
6. S. T. Stoy—"Cryogenic Insulation Development," 1959 *Cryogenic Engineering Conference Proceedings*, Plenum Press Inc., New York, 1960, p. 216.
7. R. H. Kropschot, J. E. Schrodt, M. M. Fulk, and B. J. Hunter—"Multiple-Layer Insulation," 1959 *Cryogenic Engineering Conference Proceedings*, Plenum Press Inc., New York, 1959, p. 189.
8. M. V. Smoluchowski, *Anzeiger Akademie Wissenshaft Krakauer, Series A, Vol. 5*, Krakauer Academy of Science, Germany, 1910, p. 129.
9. P. Peterson—"The Heat-Tight Vessel," *University of Lund, Sweden*, 1951 (Office of Naval Intelligence Translation No. 1147, 1953).

Tips and Techniques

Large-Radius Arc

A relatively short section of a large-radius circular arc can be drawn with reasonable accuracy by the following method.

1. Compute the height of the maximum ordinate, h_0, when

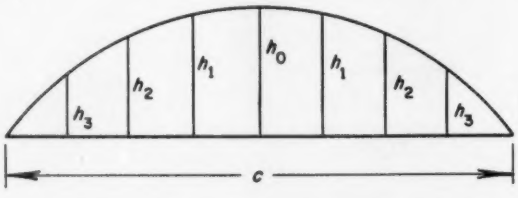
$$h_0 = r - \sqrt{r^2 - \left(\frac{c}{2}\right)^2}$$

where r is the radius of the required arc.

2. Divide the chord, c, into eight equal parts. Then, $h_1 = 15h_0/16$; $h_2 = 3h_0/4$; $h_3 = 7h_0/16$.

A smooth curve drawn through the calculated points gives an arc which is sufficiently accurate for most drafting purposes.

If additional points are needed for plotting the curve, the chord may be divided into 16 parts. The heights of the intermediate points, beginning with



the point between h_0 and h_1 are $63h_0/64$; $55h_0/64$; $39h_0/64$; $15h_0/64$. — NORMAN M. WICKSTRAND, *Harwinton, Conn.*

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A shortcut procedure for calculating

Natural Frequency of Annular Plates

WILLIAM C. ORTHWEIN
International Business Machines Corp.
Owego, N. Y.

LOWEST natural or resonant frequency of individual machine parts usually can be determined by straightforward methods, using "handbook" equations. However, when the part is in the form of an annular plate, Fig. 1, the calculations are long and tedious and cannot be readily handled on computing equipment because of the occurrence of Bessel functions in the frequency expression.

This article presents a shortcut procedure that reduces the design solution to a few simple numerical steps. Two mounting conditions for annular plates are covered: 1. Inner and outer edges clamped. 2. Inner and outer edges simply supported, or free.

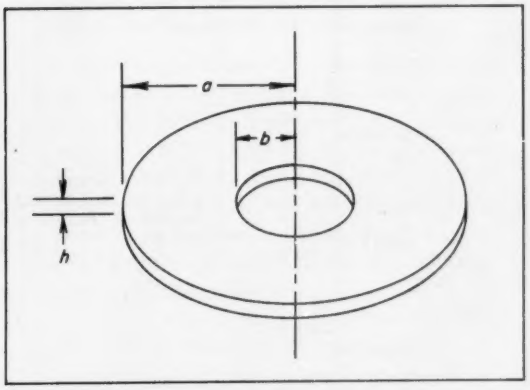


Fig. 1—Annular plate showing basic dimensions for vibration analysis.

The first resonant frequency for a plate clamped at one radius and simply supported at the other would fall between the frequency values for these two conditions.

Basic Relationships: Natural frequency of an annular plate is given by

$$f = qu^2 \left(\frac{h}{b^2} \sqrt{\frac{E}{\rho}} \right) \qquad (1)$$

where f = lowest resonant or natural frequency, cps; E = Young's modulus of elasticity, psi; ρ = density, slugs/cu in. (32.2 × slugs/cu in. = lb/cu in.); b = inside radius of plate, in.; h = thickness of plate, in.; u = parameter determined from eigenvalue analysis involving Bessel functions; and q = dimensionless factor dependent on Poisson's ratio ν.

Values of u for different values of the ratio of outside radius to inside radius can be determined directly from the conversion scales given in Fig. 2. One scale applies only to clamped plates, the other to simply supported plates. Values of q for different values of Poisson's ratio ν can be determined directly from the third conversion scale in Fig. 2.

In practice, the conversion scales are essential since the frequency, Equation 1, is linearly dependent only upon the thickness and not upon the radius ratio. Hence, design changes based upon linearizing the dependent variable, f, as a function of radial dimensions can often lead to erroneous results.

First step in solving for the natural frequency of

an annular plate is to calculate the value of

$$\frac{h}{b^2}\sqrt{\frac{E}{\rho}}$$

Next, the values of q, corresponding to Poisson's ratio ν for the plate material, and u are found from the conversion scales, Fig. 2. Then, Equation 1 is solved for the natural frequency.

Example: Find the natural frequency of a simply supported annular plate where $a = 10$ in., $b = 1$ in., $E = 1 \times 10^7$ psi, $h = 0.01$ in., $\nu = 0.30$ and $\rho = 5 \times 10^{-3}$ slugs/cu in. Then,

$$\frac{h}{b^2}\sqrt{\frac{E}{\rho}} = \frac{0.01}{1^2}\sqrt{\frac{1(10)^7}{5(10)^{-3}}} = 447 \text{ cps}$$

From Fig. 2, at $\nu = 0.30$, $q = 0.0482$. From the conversion scale for a simply supported plate, Fig. 2, at $a/b = 10/1 = 10$, $u = 0.38$, and $u^2 = 0.1444$.

From Equation 1

$$f = 0.0482(0.1444)(447) = 3.11 \text{ cps}$$

which is the lowest or fundamental natural frequency.

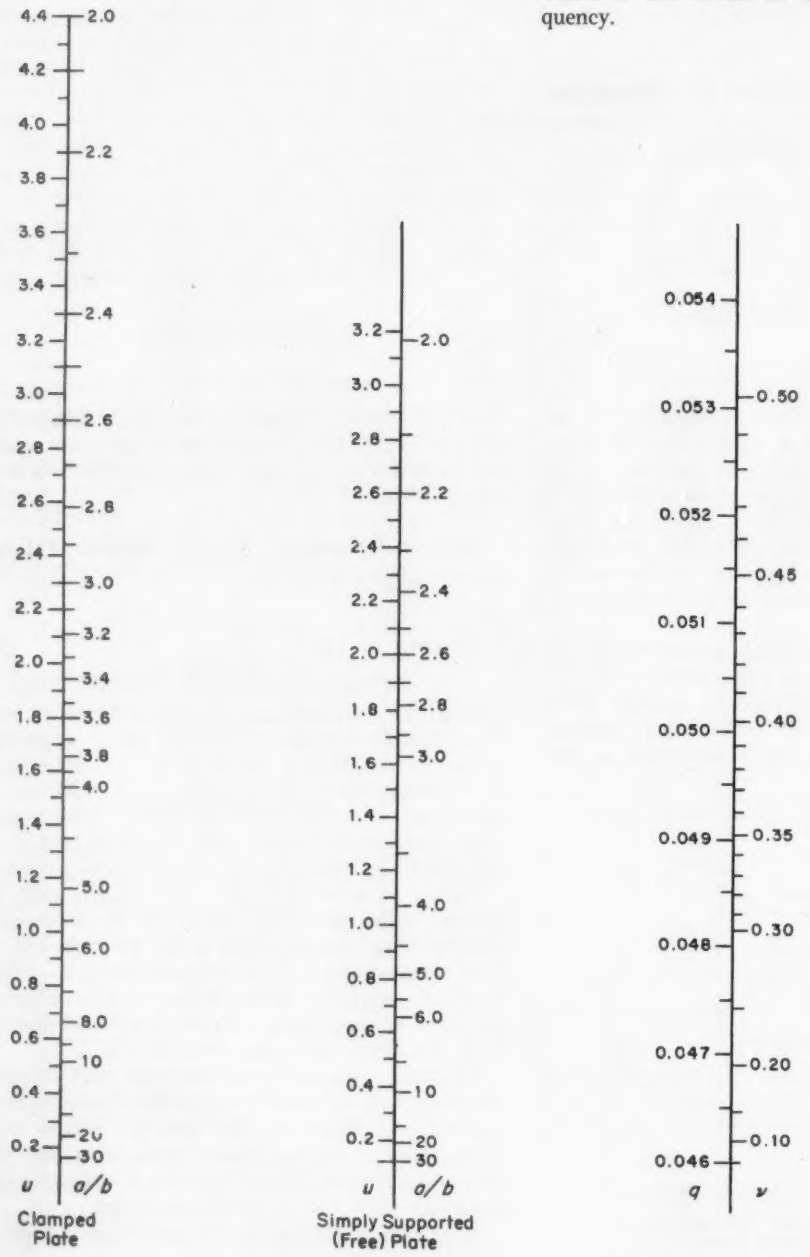
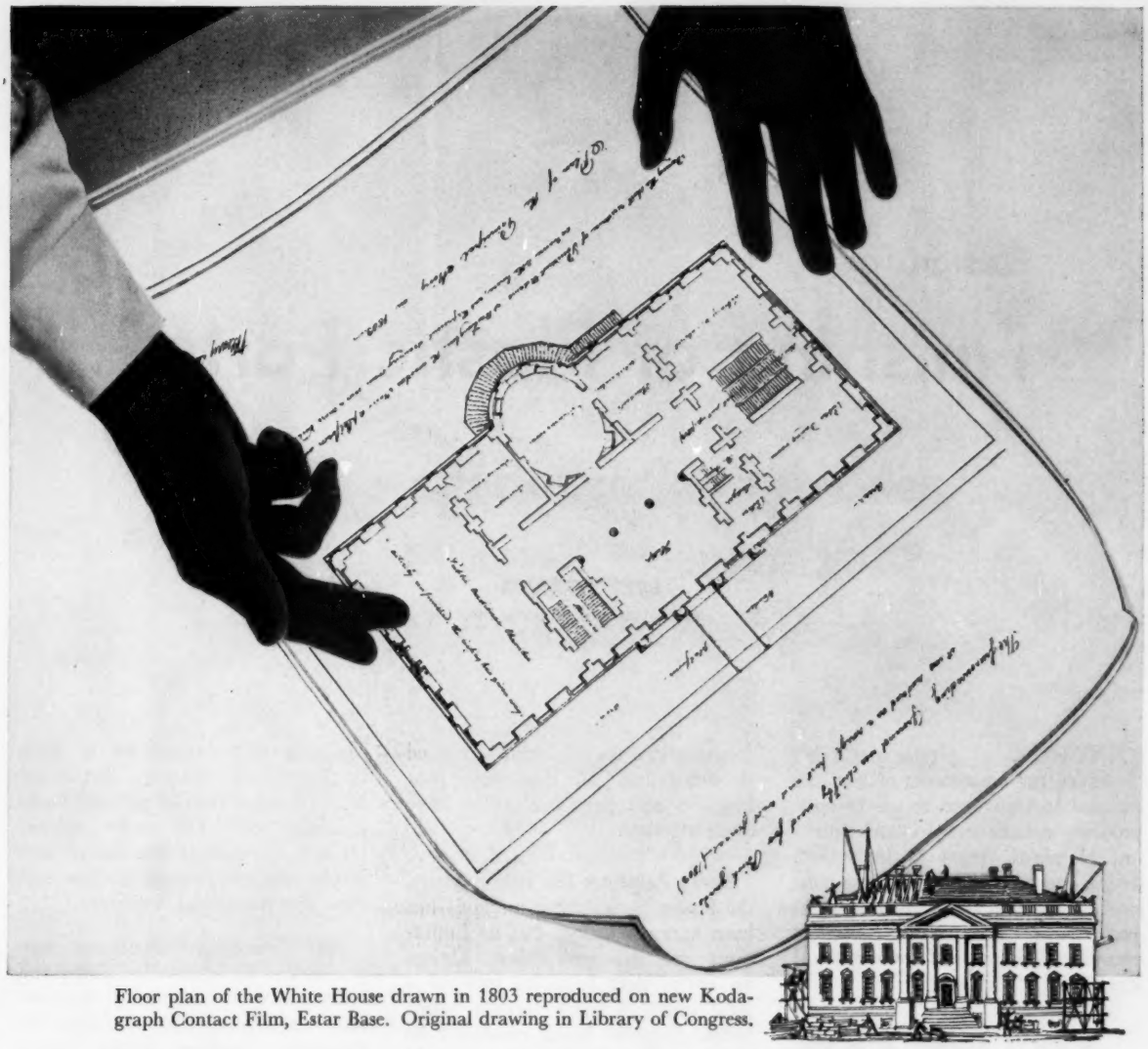


Fig. 2 — Conversion scales for determining calculation factors u and q.



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Design for

Finishing of Plastic Parts

FRED BORRIES
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Chicago, Ill.

FINISHING of plastic parts involves the treatments of surfaces exposed to sight and touch in end-product assemblies. When finishing of plastic parts is important, design must reflect many more considerations than those for operation and manufacture. Basic finishing considerations are of two general kinds:

1. Methods of decoration to be used. Will the part be hot-stamped, sprayed, metallized or screened? These operations will be partially determined by the function of the part. In certain instances, a combination of methods will be desirable.
2. Materials to be used. Most plastics can be decorated by several methods.

Normally, finishing is concerned with the exact placing of paint breaks, color pads, recessing and/or raising of letters and numerals. Finishing design avoids sharp corners, deep crevices and other irregularities that would tend to set up strains in materials.

A current trend to larger and larger parts, such as single-piece television masks, has been dictated by the cost savings possible with these moldings. To give these parts the appeal of multiple color moldings, and the appearance of multiple construction, the molder has turned to decorating. In this way, part function and part decoration have come together.

Spray Painting: For twenty years, the leader in finishing methods has been spray painting, but its limitations are still overlooked. Unless an entire part is to be sprayed a solid color, it must have a paint break. A paint break need not be objectionable. In fact, it can add to the appearance of a part. There are several ways to accomplish this, but one method will generally stand out. One colored area may be raised over another. This rise need be at least 0.020 in., but less than 0.125 in. A band of any width, stepped down 0.020 to 0.030 in. can separate two colors and have a third color sprayed into it.

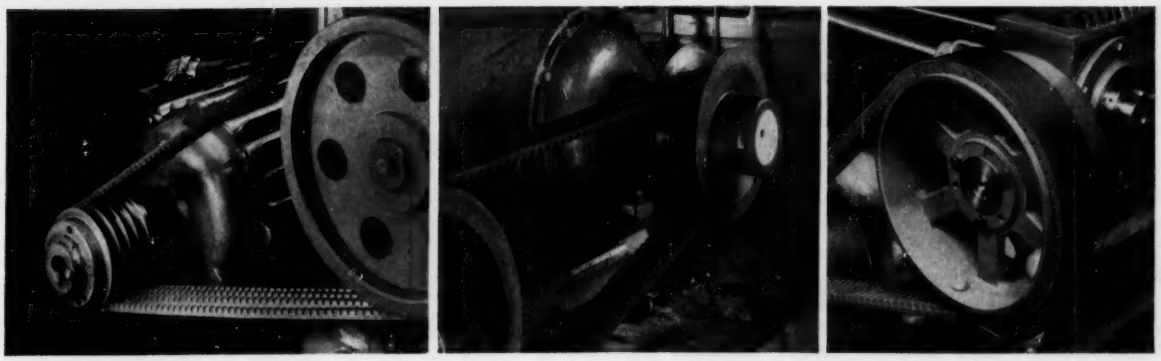
The main thing to remember in designing paint breaks is masking. Masks are basically of three types: Plug, lip, and shield. The size of the part is important when masking is considered. A well-made mask will allow for very little size change of the part. Sequence of operations may also dictate the type of paint breaks. Sequence becomes still more important when the vacuum plating method is used to obtain bright areas. Metallizing is easier to accomplish if no masking is done in the vacuum chamber. But raised bright frames around painted backgrounds are more easily accomplished by making the entire part bright and spraying on a color coat over the metallized substrate.

Hot Stamping: Continual improvement in bright metallized roll leafs makes hot stamping the second leading method of decorative finishing. Leading edges, raised monograms, and engraved lettering that would be far too costly to metallize have become economical and feasible for most finishers.

The only design consideration for hot stamping is to provide outer surfaces which can be reached with a die. As long as the surface and the die are parallel and the surface can be held rigid, it can be decorated. Unfortunately, it is difficult to coat more than one square inch at one stamping.

Silk Screening: Designs for screening must provide room for the screen itself. A minimum clearance of 3/4 in. should be provided to any obstruction.

Vacuum Metallizing: A distinct advantage is that metallizing can be done without masking. It is best to metallize at a time in the process



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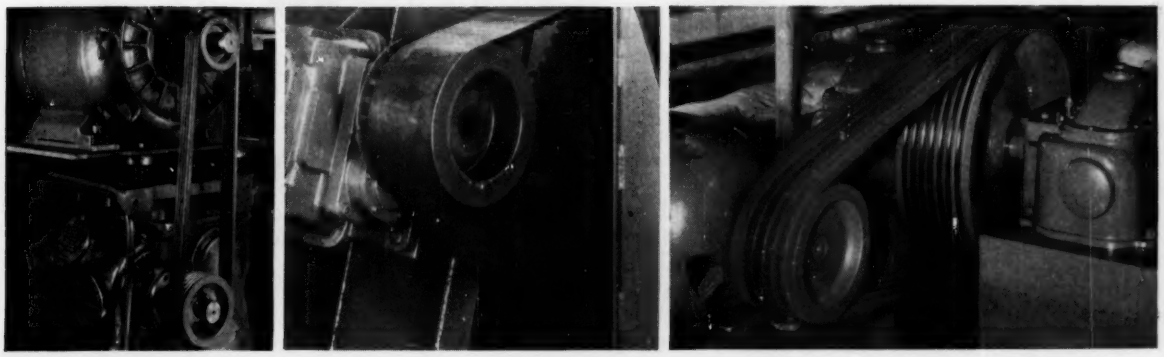

where either no masking or a loose fitting mask will do the job.

Contours: In designing for finishing, it is a necessity to avoid sharp corners. No finish adheres as well on a corner as it does on a flat surface. Paints will not achieve proper build-up on sharp edges.

Finishes applied to large flat areas often show more flaws than are tolerable. Plastic has a natural static charge. This charge tends to pull dust out of the air. Any flat surface shows dust far greater than a surface that has been properly broken.

Markings: Names or emblems in recessed or raised areas generally should be a contrasting color. If they are on the second surface, being used for three-dimensional effect, there are two ways of finishing: 1. Fill the lettering and then clean the surface of the unwanted color. 2. Plug and spray the background color then spray the fill coat.

Letters that are to be filled and then wiped should be big enough to get the coating in and not so large that it can be wiped out. Of course, the size of letters depends greatly on the overall size of a part. But to fill and wipe, a numeral or letter should be no more than 0.40 to 0.50 in. broad and no shallower than 0.020 in. To mask a letter efficiently, 0.030 to 0.075 in. can be the breadth, and 0.030 in. the absolute minimum depth. Broader numerals and letters can be effectively filled with a lap mask.

Lettering or numerals on the front or first surface can generally be designed for hot stamping. It is only necessary to have the lettering face flat and raised at least 0.015 in. above the surface. If the first surface lettering is to be depressed, it should be large enough to accommodate tip masks, or small enough to allow for filling and wiping.

One-Piece Construction: This has been successfully accomplished quite often in the past and will be a more accepted practice in the future. Generally, this type of part has clear windows, dial scales, etc., surrounded by frames. The door to this type of finishing was first opened by the use of metallized raised areas around clear windows to give the appearance of glass enclosed by chrome. Today, much larger parts achieve many different effects, based on the same ideas.

SPE Paper No. 19-1, "Design for Plastic Finishing," presented at the Seventeenth Annual Technical Conference of the Society of Plastic Engineers, Washington, D. C., Jan., 1961, 2 pp.

techniques

Fully Plastic Moment Of a Cantilever Beam

B. G. Neal, professor of civil engineering, University College of Swansea, Wales, Great Britain

The value of the fully plastic moment caused by normal and shear forces acting simultaneously on a cantilever beam. The beam is rectangular in cross section and subjected to both shear and normal forces at the free end. Upper and lower limits to be collapse load are determined, and the results are presented in the form of interaction relations between the shear and normal forces and the bending moment at the clamped end of the cantilever at collapse.

ASME Paper No. 60-WA-102, "The Effect of Shear and Normal Forces on the Fully Plastic Moment of a Beam of Rectangular Cross Section," presented at the Winter Annual Meeting, New York, Nov-Dec., 1960, 6 pp.

Three-Dimensional Photothermoelasticity

Herbert Tramposch, associate engineer, Product Development Laboratory, International Business Machines Corp., and George Gerard, associate director of research, College of Engineering, New York University.

Evaluation of a sandwich technique for application to three-dimensional photothermoelasticity. The sandwich technique utilizes an embedded polariscope consisting of two sheets of polarizing material cemented within a plastic model. The evaluation included strength tests of cemented joints, photoelastic tests of simple bending models and a sphere, all under mechanical loading. The technique proved to be rather simple to apply particularly since the resulting fringe patterns are readily interpreted. The sandwich technique was then applied to thermal-stress problems associated with a thick-walled cylinder under steady-state conditions. The results obtained indicate the general applicability of the sandwich technique to three-dimensional stress problems generated by mechanical or thermal loads. Since other experimental thermal-stress-analysis methods are not highly developed, photothermoelasticity would seem to be particularly useful.

ASME Paper No. 60-WA-49, "An Exploratory Study of Three-Dimensional Photothermoelasticity," presented at the Winter Annual Meeting, New York, Nov.-Dec., 1960, 6 pp.

Design Computations for Special Optical Systems

Raphael Boolsky, consultant, Geneva, Switzerland

A new axiomatic method for analysis and design of wide-aperture, wide-angle, and other special optical systems. This method permits determination readily of the optical properties which would be compatible with an optical system in its early planning stage, without requiring a detailed knowledge of all parts of the system.

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SMPTE Paper No. 42, "New Methods in Design and Computing for Special Optical Systems," Proceedings of the 5th International Congress on High-Speed Photography, Oct., 1960.

Finding Dynamic Strain By High-Speed Photography And Photoelastic Coatings

C. A. Cole Jr. and John F. Quinlan, U. S. Naval Medical Field Research Laboratory, and Felix Zandman, Instruments Div., The Budd Co.

Recent development of a photoelastic-coating technique for investigation of dynamic-strain phenomena in opaque structural parts. The part is coated with photoelastic plastic film and statically or dynamically loaded. Strains are transmitted from the surface of the

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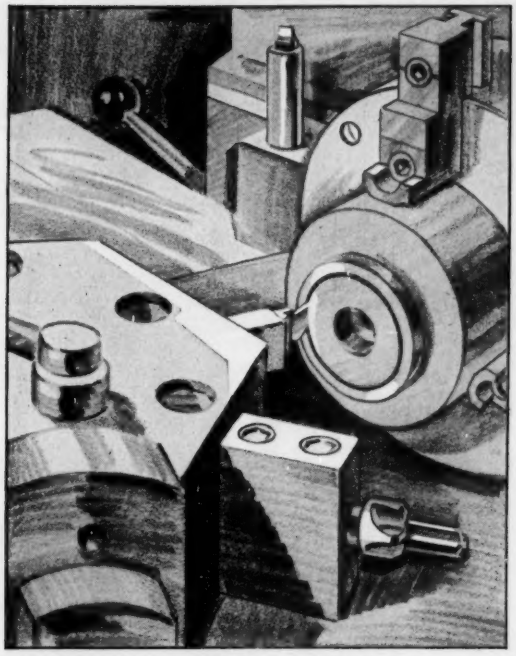

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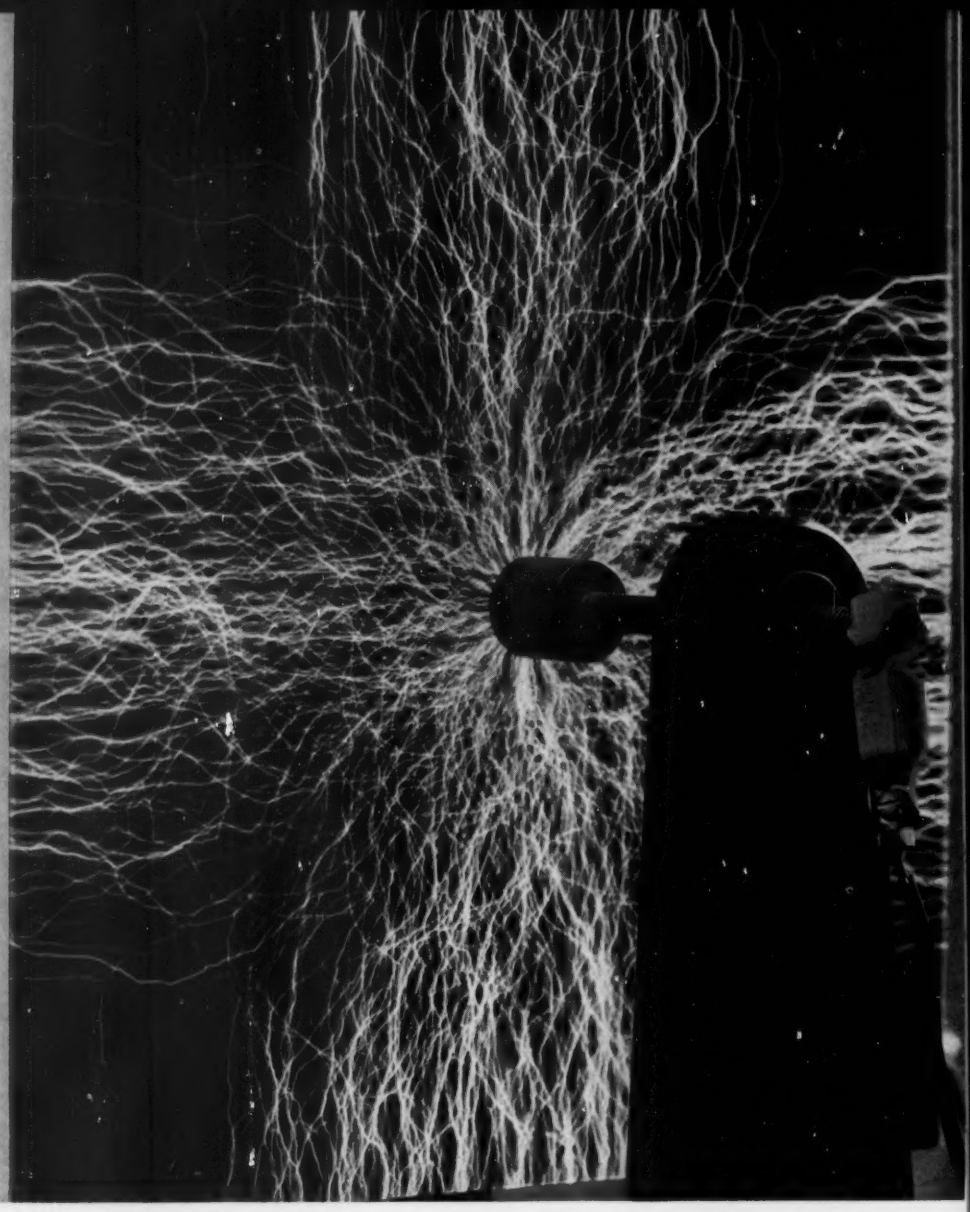

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part to the plasma coating. The interference pattern obtained when the plastic is illuminated with polarized light is interpreted by classical photoelastic methods. The pattern is recorded by a camera in which photographic rate is chosen as a function of velocity of the dynamic-strain phenomena.

SMPTE Paper No. 17, "The Use of High-Speed Photography and Photoelastic Coatings for the Determination of Dynamic Strains," Proceedings of the 5th International Congress on High-Speed Photography, Oct., 1960.

hydraulic

Effects of Impeller Design And Surface Roughness In Centrifugal Pumps

F. A. Varley, senior lecturer, Royal Military College of Science, Shrivenham, England

Data on the effects of the various impeller design elements on the performance of a 2-in. double-entry pump. The decisive parameters determining the performance of the impeller are shown to be the number of blades and their outlet angle. The inlet angle and the blade profile are of relatively minor importance. Roughness of the impeller surfaces, both internally and on the outside of the shrouds, decreases the pump's efficiency but increases its output.

Analysis of the test results with artificially roughened impellers demonstrates that current conceptions of the disc friction and the energy balance sheet for a pump are untenable.

IME Paper No. 13/60, "Effects of Impeller Design and Surface Roughness on the Performance of Centrifugal Pumps," 1961, 17 pp.

Extreme Range Axial Compressors

Donald O. Millar, engineer-in-charge, Value Analysis Section, Allis-Chalmers Mfg. Co.

Presentation of actual performance results of multistage axial compressors operating at extreme design conditions, particularly with regard to pressure ratio and Reynolds number.

There is considerable literature covering the effect of low Reynolds number on individual cascades and

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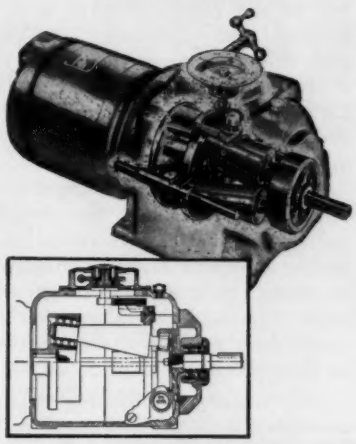

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Circle 453 on Page 19

single-stage test compressors. Numerous papers have been published on the effects of low Reynolds number in the combination of a gas turbine and compressor. Most authorities also agree that for Reynolds numbers below approximately 2.2×10^5 there is a decrease in deflection and consequently a decrease in pressure-ratio capabilities.

Data presented in this paper are sufficient to establish the design point for an axial compressor operating at extreme ranges of pressure ratios and quite extreme ranges of pressure level. More information is needed for the design of compressors for Reynolds numbers below 25,000.

ASME Paper No. 60-WA-176, "Considerations in the Design of Extreme Range Axial Compressors," presented at the Winter Annual Meeting, New York, N. Y., Nov. 27-Dec. 2, 1960, 4 pp.

lubrication

Lubrication of Worm Gears

J. Whittle, Shell Research Ltd., Thornton Research Center, Chester, England

Development of a premium grade of lubricant which appears to meet most basic requirements:

1. Friction should be lower than with a mineral oil. Low friction implies low oil and metal temperatures and also low power loss which can lead to fuel economy.
2. Wear and pitting should be less than with mineral oils. To some extent this should follow from the lower friction but a new lubricant should give inherently less wear and pitting than mineral oils.
3. Oxidation stability should be better than inhibited mineral oil. Because rate of oxidation is a function of oil temperature and concentration of catalyst (copper from the bronze in soluble form or in the form of small particles) lower temperatures and lower wear should improve oxidation. The lubricant should also possess good inherent or induced oxidation stability.
4. Viscosity-temperature relation should be as good as, or better than, the normal grade of worm-gear oil. Worm-gear oils usually have a viscosity index about 100. This ensures that channeling or excessive oil drag is minimized at cold-starting conditions.
5. The improved lubricant should have no serious detrimental side effects.
6. Overall it should be economically competitive with mineral oils.

IME Paper No. AD 7/60, "Lubrication of Automotive Worm Gears," presented at an ordinary meeting of the Automobile Div., London, Jan., 1961, 15 pp.

mechanical

Centrifugal Clutch Couplings

James E. Ettorre, assistant chief engineer, Hilliard Corp.

Centrifugal clutches permit rapid acceleration of a motor to peak torque and appreciably reduce motor current and heating. They also provide an automatic means for connecting an internal combustion engine to its load by simple throttle control. Over-design—the selection of a clutch of larger capacity than necessary—often results in pulling down the driver's speed so that optimum performance is not realized. An understanding of the factors which affect the capacity of the centrifugal clutch is important in determining the proper selection. A centrifugal clutch-coupling which can provide for misalignment be-

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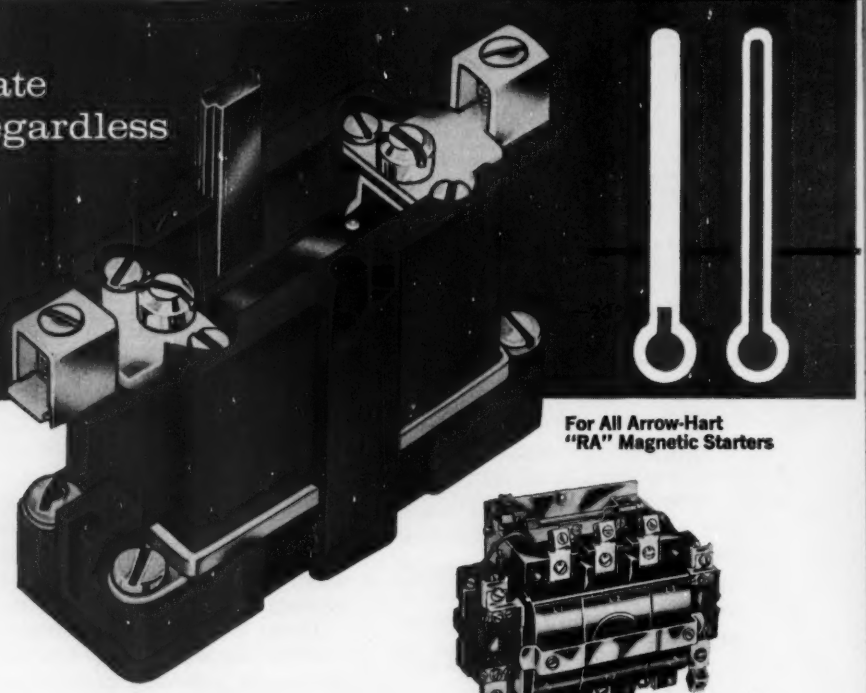

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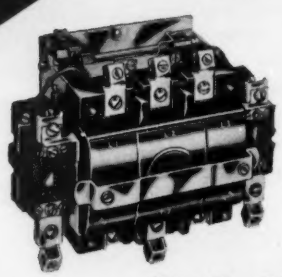


Nema Sizes 0 through 5

tween the driving and driven machines without significant impairment of its speed-torque properties provides a compact and economical arrangement.

ASME Paper No. 60-WA-173, "The Centrifugal Clutch Coupling," presented at the Winter Annual Meeting, New York, N. Y., Nov. 27-Dec. 2, 1960, 11 pp.

Optimum Design of Helical Compression Springs

R. J. Erisman, chief engineer, Design Analysis, International Harvester Co.

Design charts which enable a designer to determine rapidly the proper proportions for minimum-weight springs. Derivations are based on generalized assumptions, permitting a wider application to typical problems than is possible with more specialized initial assumptions.

Two design conditions are considered. The first, representing the case where no stress correction is included, should be limited in use to statically loaded springs. The outside diameter cannot be optimized separately, but in all cases provides lighter weight springs with smaller dimensions.

The second design condition represents the case where the operating stress is modified by the Wahl correction factor. Springs designed in accordance with this procedure can have a wider application since automatic stress compensation is made for the effect of changing spring indexes. In this case, the outside diameter has an optimum value depending upon the original stipulations of the problem. By combining this optimum value with the optimum wire diameter and its resulting solid height, a designer will obtain a true minimum-weight spring.

ASME Paper No. 60-WA-215, "Optimum Design of Helical Compression Springs," presented at Winter Annual Meeting, New York, N. Y., Nov. 27-Dec. 2, 1960, 6 pp.

Machine Tool Research, Design, and Utilization

D. F. Galloway, director of research, Production Engineering Research Association, Melton Mowbray, England

Extensive coverage of the subject under these headings: Criteria of performance, terminology and specifications, accuracy, deflection, vibration, spindle bearings, thermal stability, slideways, drives, power consumption, efficiency, automation, cutting-fluid systems, attachments and operations, ergonomics, and maintenance.

IME Paper No. 96/60, "Machine Tool Research, Design, and Utilization," presented at the meeting of the Institute of Mechanical Engineers, London, Dec., 1960, 72 pp.

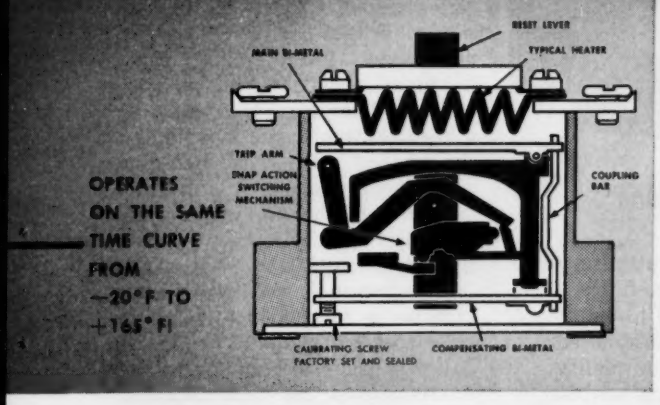
electrical

Small Electronic Parts under Intense Sound and Vibration

Denis U. Noiseux, senior consultant, Bolt Beranek and Newman Inc.

Early results from a broad program to investigate the effects of intense sound fields on electronics. Results can be used to help in answering the following questions: 1. Should a component be mounted rigidly or resiliently? 2. Is there a preferred

MOTOR CONTROLS



Here for the first time is a compact, dependable overload relay that compensates for both heat and cold. As shown here, the balancing or compensating bi-metal and the working bi-metal are identical in size and construction and are joined by a coupling bar. As the ambient temperature rises above or falls below 72°F, the balancing bi-metal operates through the coupling bar to maintain the same tripping time over a temperature range from −20°F to +165°F. Compensating action is fully automatic. Relays use standard A-H Heaters and operate equally well with either quick-trip or regular types. The switching mechanism itself employs the same positive snap-action featured in all A-H Overload Relays. Calibrating screw permits precise adjustment at the factory and needs no further adjustment. Available in ratings from 25 to 300 amperes, continuous current, these new Ambient Compensated Relays can be supplied with all sizes of Arrow-Hart "RA" Magnetic Starters . . . or as individual units for use as separately mounted relays.

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Circle 454 on Page 19

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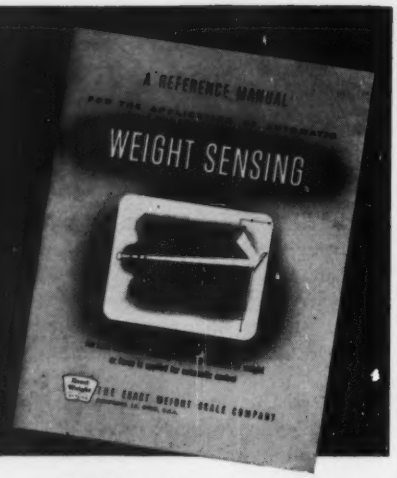

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orientation for mounting a sensitive component on a vibrating plate? 3. What vibration tests should a sensitive electronic component be given?

Conclusions are limited to small electronic components where the largest dimension is about one inch. A fairly definite conclusion is that small electronic components which are insensitive to vibration are also insensitive to sound excitation. It follows that small electronic components can be tested first in vibration.

Another conclusion is that a vibration test of small electronic components at 1-G acceleration is more severe than a pure tone test in a standing wave tube.

It appears preferable to cement (or clamp) small components on the vibrating surfaces than to tie them by their electrical leads.

SAE Paper 236C, "Response of Small Electronic Components to Intense Sound Fields and to Vibration," presented at the National Aeronautic Meeting, Los Angeles, 9 pp.

High Speed Communication Of Graphic Intelligence With Hard Copy Readout

John R. Shonnard, Westrex Corp., Div. of Litton Industries

Background, current status, and future plans for telegraphic transmission of printed matter the size of newspapers. Entire proof pages, headlines, texts, screened pictures, and rule lines must be scanned at a line density adequate to reproduce the smallest letters and half-tone dots necessary to achieve acceptable quality from the presses. Japanese newspapers particularly have a need for such a system.

Experiments showed 400 lines per inch to be adequate for the small type faces, but marginal for 65-line half-tone pictures. Scanning at 800 to 1000 lines per inch produced excellent results with type and good results with 65 to 75-line screened copy.

A fundamental conflict is that increased resolution increases transmission time or band width in proportion to the square of the scanning-line density (likewise, the cost of the transmission circuits). However, wide-band channels cost significantly less per bit than narrow-

band channels. The problem is to design equipment that will make efficient use of the wide-band channels where available.

AIEE Paper No. CP 61-45, *"High Speed Communication of Graphic Intelligence with Hard Copy Readout," presented at the AIEE Winter General Meeting, New York, Jan.-Feb.*, 1961, 6 *pp.*

Optimum Systems from Nonideal Components

T. R. Williams and J. B. Thomas, Princeton University, School of Engineering, and J. K. Wolf, USAF, Rome Air Development Center

Techniques in the synthesis of optimum control systems. Often, the basic circuit is fixed and the designer must choose values for a finite number of parameters. These parameters relate to components which possess exactly their nominal values. This paper considers situations where the actual values of the components differ from their nominal values in some random fashion. The optimization parameters can be treated as random variables whose probability densities have one or more variable moments.

If more than one parameter is involved in the optimization, a joint density function must be specified.

AIEE Paper No. 61-86, *"The Synthesis of Optimum Systems from Non-Ideal Components," presented at the AIEE Winter General Meeting, New York, N. Y., Jan.-Feb.* 1961, 7 *pp.*

TO OBTAIN COPIES of papers or articles abstracted here, write directly to:

AIEE—American Institute of Electrical Engineers, 33 West 39th St., New York 18, N. Y., papers 50 cents to members, one dollar to nonmembers.

ASME—American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., papers 50 cents to members, one dollar to nonmembers.

IME—The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London S.W. 1, England.

SAE—Society of Automotive Engineers, 485 Lexington Ave., New York 17, N. Y., papers 50 cents to members, 75 cents to nonmembers.

SMPTE—Society of Motion Picture and Television Engineers, 55 W. 42nd St., New York 36, N. Y.

SPE—Society of Plastics Engineers, 65 Prospect St., Stamford, Conn.

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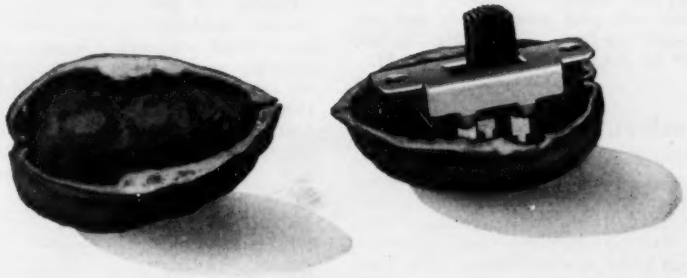

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Circle 456 on Page 19

Helpful Literature
for Design Engineers

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Bolts, Nuts, Screws, Washers

Catalog lists many types of fasteners designed to meet any specific requirement. Included are screws, bolts, nuts, washers, in various head styles. Also listed are Sems, Tuff Tites, Lev-L-Screws, Schweppe Stud, and miniatures. Pictures are provided, and brief specifications and advantages are listed. Pheoll Mfg. Co. Inc, 5700 W. Roosevelt Rd., Chicago 50, Ill.

Circle 701 on Page 19

Synchros, Rotary Components

New booklet provides data on various synchro shafts, synchro conventions, synchros of several sizes, pancake units and resolvers, linear transformers, servo motors and generators, and gearheads. Many tables, wiring diagrams, line drawings, performance curves, and photographs are incorporated. 34 pages. Clifton Precision Products Co. Inc., Clifton Heights, Pa.

Circle 702 on Page 19

Rotary Gear Pumps

Nitralloy rotary gear pumps, available in capacities from ¼ to 146 gpm at pressures to 2000 psi, are described in Bulletin 43. They handle materials with viscosity ratings from 300,000 to 30 ssu. Bulletin describes the range of sizes and capacities and lists many of the pumping applications. Advantages of the units are pointed out. Northern Ordnance Inc., Minneapolis 21, Minn.

Circle 703 on Page 19

Commercial Thermostats

Bulletin 3500 describes Type G commercial thermostats, featuring exposed or enclosed bimetal-disc thermal elements. Bulletin illustrates the major units in the line, and gives technical details on optional features such as available terminals, terminal mountings, and flange-mounted assemblies. Ranges, tolerances, differentials, and ratings are also given. 4 pages. Stevens Mfg. Co. Inc., P. O. Box 1007, Mansfield, Ohio.

Circle 704 on Page 19

V-Belts

Design features and performance advantages of company's V-belts are detailed in Bulletin M-201. Included are Condor V-belts and fractional-horsepower belts, Condor Double-V belts, CX fully molded V-belts, and Poly-V drive. In addition to ordering information and specifications, bulletin includes graphically illustrated sections on the comparative advantages of straight sidewall construction in V-belts. Tables and diagrams are incorporated. 8 pages. Manhattan Rubber Div., Raybestos-Manhattan Inc., Passaic, N. J.

Circle 705 on Page 19

Portable Lamps

Catalog 116 covers incandescent, fluorescent, combination, and magnifying lamps which are portable, functional, and precision made. They are suitable for use in drafting rooms, offices, and laboratories. Units are pictured and all specifications are given. 4 pages. Luxo Lamp Corp., Dock St., Port Chester, N. Y.

Circle 706 on Page 19

Industrial Heating Units

Catalog Supplement CS-600 contains specifications and product illustrations of Chromalox electric heater bands, air-heating elements, blower-type heaters, immersion units, engine heaters, mineral-insulated heating table, special radiant heaters for process and comfort heating, controls, and various other elements and equipment. 25 pages. Edwin L. Wiegand Co., 7500 Thomas Blvd., Pittsburgh 8, Pa.

Circle 707 on Page 19

General-Purpose Relays

Bulletin WU-09 shows compact, 25-amp, Diamond-H relays in a variety of standard mounting arrangements, with several optional types of terminals and eight different single and double-pole contact combinations. Engineering data, specifications, dimension sketches, accessories, and typical applications are included. 8 pages. Hart Mfg. Co., 110 Bartholomew Ave., Hartford 1, Conn.

Circle 708 on Page 19

Dial Timer

Bulletin N-309 describes Series 309 pushbutton automatic-reset dial timer. It contains complete data on application, construction, installation, specialized functions, electrical data, and basic circuit arrangements for control of up to four individual load circuits. Miniaturized Atcotrol pushbutton timer controls industrial processes, laboratory, and machine automation. 4 pages. Automatic Timing & Controls Inc., King of Prussia, Pa.

Circle 709 on Page 19

Electronic Air Filters

Bulletin B-100-6 contains detailed charts, tables, and other engineering data necessary to size and specify air filters both for electronic equipment of any size, and for the room or mobile equipment that contains it. Included are data on filter media, shapes, and mounting methods. Special filter applications are described, as are finishes, uses, and maintenance methods. 8 pages. Farr Co., P. O. Box 90187, Airport Station, Los Angeles 45, Calif.

Circle 710 on Page 19

Testing Equipment

Nondestructive Testing Bulletin 00-105 describes line of ultrasonic testing equipment, portable industrial x-ray, and magnetic-particle inspection equipment and supplies. Various units are pictured, and methods of testing are shown. Specifications for the units are also provided. 12 pages. Sperry Products Co., Div., Howe Sound Co., Danbury, Conn.

Circle 711 on Page 19

Electronic Products

Bound catalog of company literature available to date on electronic products. Items described include: Phono input and stub jacks; interlock, phono, and speaker plugs; turret terminals and turret terminal boards; terminal strips; shaft couplers. Assemblies are pictured with drawings showing dimensions for chassis cut-outs. Specifications are noted with design features. About 28 pages. Accurate Electronics Corp., 169 S. Abbe Rd., Elyria, Ohio.

Circle 712 on Page 19

Nut and Bolt Strength

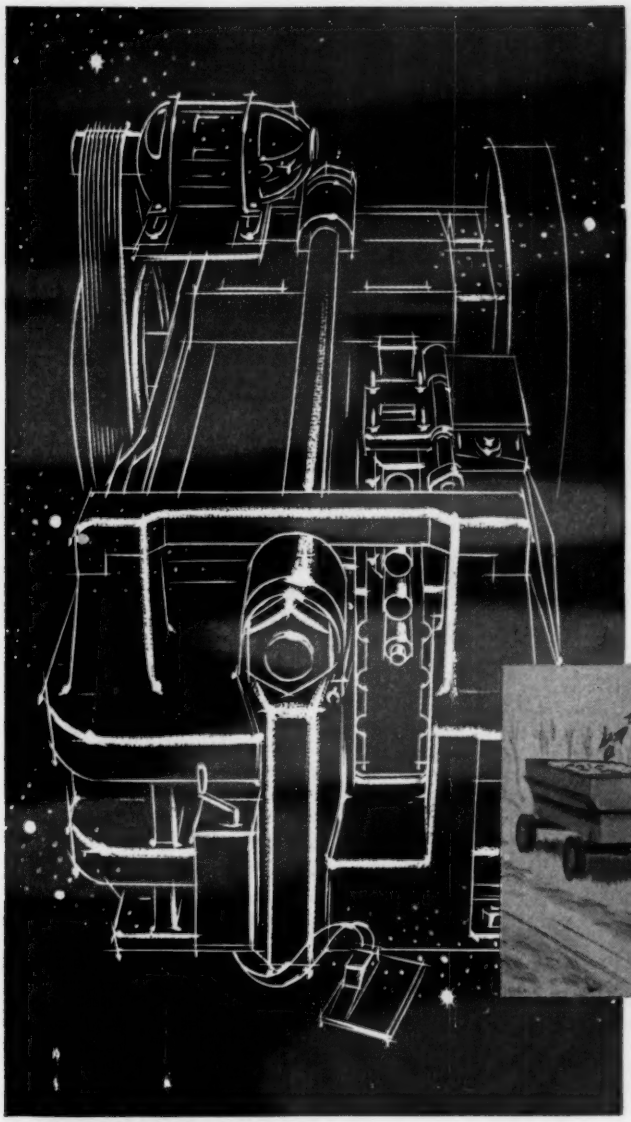
Vol. 26, No. 1 of "Harper Bolt News" provides an explanation of the kinds of strengths involved in metal bolts and nuts and tells how the strengths are achieved. Shear strength, tensile strength, yield strength, elongation, cold working, stress corrosion, creep strength, thread strength, temperature control, and metal fatigue are explained, aided by drawings. Included in the back of the booklet is a glossary of 29 commonly used metallurgical terms that appear in definitions of strength. 14 pages. H. M. Harper Co., 8200 Lehigh Ave., Morton Grove, Ill.

Circle 713 on Page 19

Drafting Templates

Template Catalog 65 carries information on 115 templates now available. Eight sections include electrical, ellipse, mechanical engineering, general, lettering, architectural, processing, and miscellaneous specialized templates. Photographs and descriptions are provided for all units. 18 pages. Rapidesign Inc., P. O. Box 429, Burbank, Calif.

Circle 714 on Page 19



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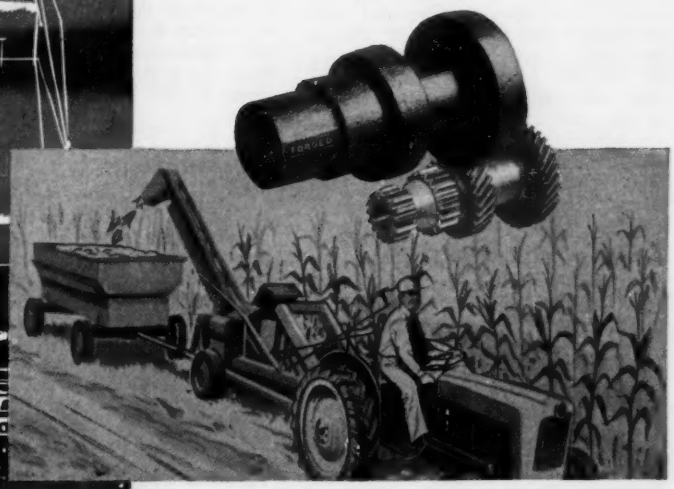

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Penton Thermoplastic

Corrosionfree properties of Penton chlorinated polyether are detailed in new technical-data booklet. In addition to charts and graphs illustrating chemical composition and structure, booklet contains extensive data on physical, mechanical, and thermal properties, and on molding and forming. Examples of use include pipes and valves, pumps, meters, tank liners, and coatings. 26 pages. Hercules Powder Co. Inc., Hercules Tower, 910 Market St., Wilmington 99, Del.

Circle 715 on Page 19

Fractional-Horsepower Motor

Bulletin B-2514 gives a comprehensive description of construction and design details of Duty Master fractional-horsepower motor. Each point is illustrated with photographs and drawings, and life-size photograph of a cut-away motor is shown in full color. Bulletin points out the many advantages and new characteristics of the motor. Complete specifications are provided. 8 pages. Reliance Electric & Engineering Co., 24701 Euclid Ave., Cleveland 17, Ohio.

Circle 716 on Page 19

Photoelectric Controls

Pocket-sized, illustrated case-history handbook details how Infrabeam photoelectric controls solved 40 typical operational problems in materials handling, equipment and personnel protection, production, and automatic control. Modulated infrared radiation enables the device to operate by reflected or interrupted beam over a long range, even under high general-light conditions. 80 pages. Electronics Div., Cramer Controls Corp., Centerbrook, Conn.

Circle 717 on Page 19

Portable Analog Computer

Illustrated brochure describes Model 3500 analog computer which weighs 28 lb. It can be used to study almost any physical system that can be described by differential equations, and can be operated on desk tops and benches by anyone who can operate a slide rule. Full specifications are given, and list of components incorporated in the unit is provided. 6 pages. Donner Scientific Co., Concord, Calif.

Circle 718 on Page 19

Rectifier Wall Charts

Two wall charts assist in the selection of optimum silicon and germanium rectifier components for basic circuits. Charts on rectifier selection (ECG-545) and on characteristics of common rectifier circuits (ECG-546) can be used independently or to complement one another. Selection chart indicates the optimum device to be used, based on average amps per cell, recurrent peak reverse voltage, and temperature. When PRV and average amps per cell are not known, data can be obtained from the characteristics chart. Color code used in both charts simplifies their use. General Electric Co., West Genesee Street, Auburn, N. Y.

Circle 719 on Page 19

Indicating Rotameter

Bulletin 131 covers Model Series 1400 indicating rotameter, designed for pressure to 5000 psig at 200 F. Bulletin incorporates detailed drawings, dimensions, and capacity tables, with full description of the series and its operation. 4 pages. Brooks Instrument Co. Inc., Hatfield, Pa.

Circle 720 on Page 19

Miniature Bearings

Complete catalog contains dimensional information, as well as engineering and applications data on miniature and instrument bearings. It offers all data necessary for the selection and specification of ball bearings for modern instruments. A feature of the catalog is the picturing of bearings in actual size. Many tables and dimensional drawings are incorporated. 40 pages. Fafnir Bearing Co., 37 Booth St., New Britain, Conn.

Circle 721 on Page 19

Precision Balls

New catalog provides data on selection of balls for environment, mechanical demands, and applications. Materials of manufacture are listed and described. Four selection charts give data on corrosion resistance of the various materials, on mechanical properties, precision, and availability of materials by grades. Sizes of balls range from 0.015 to 3-in. diam. 8 pages. Universal Ball Co., Willow Grove, Montgomery County, Pa.

Circle 722 on Page 19

Flexible Coupling

Bulletin describes new flexible coupling for instrument use. Special features are listed, and graphs present data on shaft misalignment versus radial thrust and applied torque versus angle of twist. Dimensional drawing and table provide all specifications on Model 587 BC, available from stock. 4 pages. Santa Fe Instruments Inc., 2343 Jerome Ave., New York 68, N. Y.

Circle 723 on Page 19

Socket Screws

New K16 high-performance socket-head cap screws are reviewed in Form 2707. Literature points out 14 outstanding features of the screws. Tables, curves, and application data cover principal mechanical properties. Illustrations highlight design and fabrication features, and back page provides complete dimensional specification data. 4 pages. Standard Pressed Steel Co., Box 102, Jenkintown, Pa.

Circle 724 on Page 19

High-Impact Thermoplastic

Kralastic MH, a new ABS plastic, is described in illustrated booklet. Complete physical and chemical data, including performance charts and tables, are given for the plastic, specifically developed for injection molding. Many photographs are used to demonstrate the plastic's wide range of applications and special features. 20 pages. Naugatuck Chemical Div., United States Rubber Co., Naugatuck, Conn.

Circle 725 on Page 19

Testing Instruments

Bulletin K19A contains photographs, data charts, and specifications of high-accuracy instrumentation such as vibration transducers and exciters, strain gages, load cells and beams, and engine-monitoring equipment, together with associated readout devices and recorders. Units are available for measuring, recording, and analyzing vibration and strain. Emphasis is placed upon transistorized, hand-held vibration meter which measures amplitudes from 0 to 1000 microns and has a sensitivity .of 0 to 10 microns. 4 pages Instruments & Acoustics Div., 19D Cantiague Rd., Westbury, L. I., N. Y.

Circle 726 on Page 19

Blind Rivets

Advantages of using these commercial blind rivets for fast, secure, economical fastening in blind or open applications are listed in Bulletin TCL-160. Brochure contains specifications for the rivets in plugged and hollow types in aluminum, mild steel, and Monel. Charts, drawings, and photographs provide data on rivet selection, drill-hole size, and material thickness. 12 pages. Cherry Rivet Div., Townsend Co., Box 2157-Z, Santa Ana, Calif.

Circle 727 on Page 19

Clamping Cylinders

Bulletin 91036 supplies descriptions, specifications, outstanding features, optional features, ordering data, and dimensions of clamping cylinders with 1½, 2¼, and 3-in. bores. Line drawings and tables present specification data. 4 pages. Airmatic Valve Inc., 7313 Associate Ave., Cleveland 9, Ohio.

Circle 728 on Page 19

Drive Tensioner

Bulletin contains data on Universal drive tensioner. Advantages of the unit are pointed out, and line drawings are used to present mounting dimensions and illustrations. Typical installations for both base and shaft-mounted series are shown. Information on bronze bushed idler pulleys and sprockets is also provided. Tips on idler usage are enumerated. 4 pages. Brewer Machine & Gear Co., 1441-43 N. 2nd St., St. Louis 6, Mo.

Circle 729 on Page 19

Set Screws

Pocket-sized bulletin details line of No-Mar set screws which contain a nylon insert to prevent burring or nicking of precision shafts and provide locking power. Bulletin contains dimensional tables and line drawings, and points out the advantages of these units. 4 pages. PIC Design Corp., 477 Atlantic Ave., East Rockaway, L. I., N. Y.

Circle 730 on Page 19

TEAR OUT AND PUNCH AS INDICATED FOR YOUR FILE

TEAR OUT AND PUNCH AS INDICATED FOR YOUR FILE

One in a series of technical reports by Bower

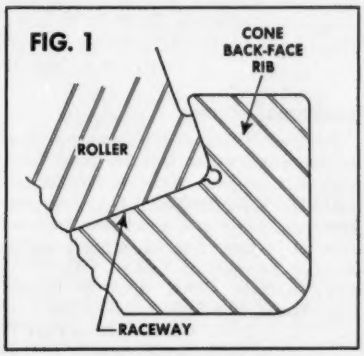
BEARING BRIEFINGS

BEARING GEOMETRY MAKES OR BREAKS BEARING PERFORMANCE

To develop high capacity and optimum performance in a tapered roller bearing, it is essential that roller alignment be accurate. Correct roller alignment, in turn, depends on a critical geometric relationship between the cone back-face rib, and the cone raceway.

Perfection in this geometric relationship compels the rollers to align themselves perfectly with respect to the bearing geometry, and each roller shares equally in the work that is imposed. Figure 1 diagrams the important elements involved.

When this rib-to-raceway relationship is incorrect (because of either faulty bearing design or manufacturing inaccuracies), rollers experience misalignment and begin to skid and skew under



load. As engineers know, poor performance and premature bearing failure are inevitable under these conditions.

In the design and manufacture of Bower tapered roller bearings, Bower engineers take great care to generate and hold an exact face angle on the cone back-face rib. In practice, this means that Bower

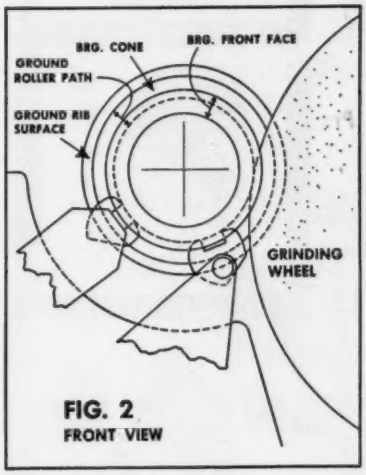
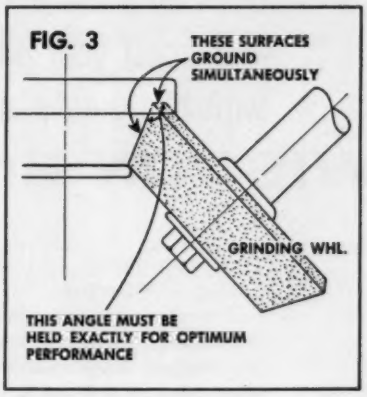


FIG. 2
FRONT VIEW

bearings are designed for maximum life and optimum performance under any operating conditions. It means that Bower bearings retain accurate roller alignment under all speeds and loads up to the maximum for which the bearing is rated.

It's one thing to develop proper bearing design on paper, but quite another to carry it out consistently in manufacture. To this end, Bower engineers were instrumental in the design and development of a unique centerless grinder on which Bower precision grinds each bearing's cone raceway and rib-face simultaneously. The results obtained from these machines invariably meet or surpass Bower's exacting requirements and assure perfect roller alignment.

Figures 2 and 3 are front and top views which illustrate Bower's technique of centerless grinding rib-faces and cone raceways together. As a result, every component in a Bower bearing is perfectly concentric about its rolling axis.



★ ★ ★ ★

When you require bearings, we suggest you consider the advantages of Bower bearings. Where product design calls for tapered or cylindrical roller bearings or journal roller assemblies, Bower can provide them in a full range of types and sizes. Bower engineers are always available, should you desire assistance or advice on bearing applications.

BOWER ROLLER BEARINGS

BOWER ROLLER BEARING DIVISION — FEDERAL-MOGUL-BOWER BEARINGS, INC., DETROIT 14, MICHIGAN

Circle 458 on Page 19

MODEL VG4D delivers 25 to 37 hp, at 1400 to 2400 rpm. Wisconsin 4-cyl. V-types range from 13 to 56 hp.
One-cyl. Models — 2.5 to 12.5 hp
One-cyl. Vertical Shaft Models — 2.5 to 9.2 hp
Two-cyl. Models — 10 to 18 hp

Cut your costs and price —or boost your profits with heavy-duty air-cooled

WISCONSIN ENGINES

Plan your power equipment around a Wisconsin Engine, and you start saving before your design leaves the board. You can use the gains to lower your price as a boost to volume — or to improve profits.

An air-cooled Wisconsin is smaller and up to one-third lighter than its water-cooled equal. There are no radiators, water pumps, fan belts, and other water-cooling parts to handle, support, or bog down your machine — and none to saddle your customers with costly repairs, servicing, and replacements in the field.

Our "spec" engineers can help you speed assembly by tailoring the engine you need—complete with electrical and mechanical modifications. You save time because the engine arrives ready to install. And we'll stand behind the quality and performance of the complete power package.

What's more, our world-wide service corps—2,000 strong—protects your equipment during power emergencies wherever it is used. Get Bulletin S-249 covering the entire line of Wisconsin Engines, 3 to 56 hp. Write Dept. O-11.

WISCONSIN MOTOR CORPORATION
MILWAUKEE 46, WISCONSIN
World's Largest Builders of Heavy-Duty Air-Cooled Engines

O-277

HELPFUL LITERATURE

Vacuum Filters

Circular 1037 announces a new line of vacuum filters. Colorful brochure explains how vacuum filters operate, and catalogs two new types, one for removing dirt and water, and one for removing oil, dirt, and water. These are listed in sizes from ¼ through 5-in. pipe flanges. 4 pages. Wilkerson Corp., 1646 W. Mansfield Ave., Englewood, Colo.

Circle 731 on Page 19

Resilient Couplings

Revised Bulletin 4100 presents complete line of torsionally resilient Steelflex couplings. New pages, additional coupling types, dimensions for larger sizes, and easier method of selection are included. Explanation of Grid-Groove coupling design is included and illustrated. Charts and tables contain up-to-date engineering data. 32 pages. Falk Corp., Box 492, Milwaukee 1, Wis.

Circle 732 on Page 19

Miniature Flowmeter

Designed for flow rates as low as 10 cc per minute with an accuracy of 1 per cent of full scale, miniature magnetic flowmeter is fully described in Specification Bulletin 10D1415A. Factual data on materials of construction, capacities, operational limits, and other essentials are given, along with dimensional drawings. Design features are pointed out. 4 pages. Fischer & Porter Co., 747 Jacksonville Rd., Warminster, Pa.

Circle 733 on Page 19

Electric Motors

Publication GEA-6927B lists features and advantages of Thinline motors for limited-space applications. Illustrated bulletin shows full line of the motors, rated 1-5 hp in dripproof and enclosed construction. Many cutaway photographs are used to point up the special features of the units. Table of interchangeable endshield dimensions is provided. 8 pages. General Electric Co., Schenectady 5, N. Y.

Circle 734 on Page 19

Leakproof Pumps

Features of Series G Chempump, such as automatic thrust balance, large bearings, and oil-filled stator cavity, are detailed in Bulletin 2050. Complete performance curves and a detailed cross-section of a new line of canned pumps are also incorporated. 4 pages. Chempump Div., Fostoria Corp., Buck & County Line Roads, Huntingdon Valley, Pa.

Circle 735 on Page 19

Rotary Switches

Two-color brochure gives detailed information on Blue Line modular rotary switches. Text describes advantages of the units. Also shown are technical specifications, photographs, and a wide variety of accessories and attachments available from stock. 4 pages. American Solenoid Co. Inc., U. S. Highway 22, Union, N. J.

Circle 736 on Page 19

Temperature Regulators

Temperature-regulating devices which control air or liquid temperatures within a fraction of a degree are covered in Catalog 360. Various components described are available separately or jointly as shown in typical applications outlined in the catalog. Bimetal and mercury thermoregulators, heaters, relays, stirrers, pumps, and transformers are included. Photographs, drawings, and tables provide all data on features and specifications. 32 pages. American Instrument Co. Inc., 8030 Georgia Ave., Silver Spring, Md.

Circle 737 on Page 19

Metal-Cased Switches

Catalog 30-1 gives complete details on horsepower-rated KL heavy-duty, metal-cased switches and double-break BK-1 switch. Listings include limit switches, safety switches, and aircraft switches. Pictorial index shows location of dimensional drawings, descriptions, force and movement specifications, electrical ratings, and photograph for each switch listed. Data on bases, circuit arrangements, NEMA standard definitions of precision snap-acting switch terms, and selection are also included. 16 pages. Unimax Switch Div., W. L. Maxson Corp., Ives Road, Wallingford, Conn.

Circle 738 on Page 19

Centrifugal Pumps

Bulletin 721.6 provides complete specifications, interchangeability chart, performance curves, and dimensions for Model 3405 single-stage, double-suction centrifugal pumps. Large sectional view of one unit is provided, as well as many tables, graphs, and line drawings. 16 pages. Goulds Pumps Inc., 219 Black Brook Rd., Seneca Falls, N. Y.

Circle 739 on Page 19

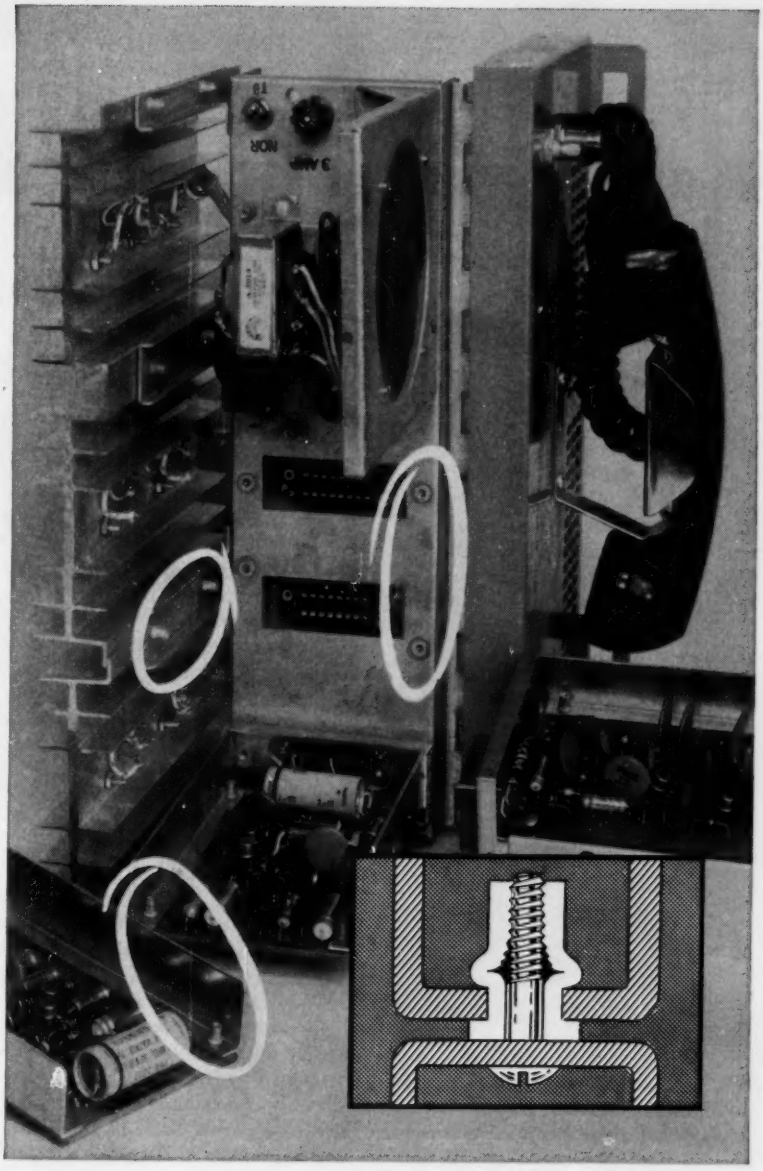
Printed-Circuit Connectors

Complete specifications, outline drawings, and illustrations of Series 600-7 Continental printed-circuit connectors that offer a tandem design are contained in Form 1260. All electrical and mechanical ratings, dimensions, and materials are listed. 4 pages. Electronics Div., DeJur-Amsco Corp., 45-01 Northern Blvd., Long Island City 1, N. Y.

Circle 740 on Page 19

O-Ring Specification

Simple-to-use slide chart assists design and production engineers in the specification of metal O-rings. Chart covers ring diameters from ¼ to 50 in. and includes specifications for plain, plated, and coated rings. Proper installation dimensions are quickly and easily determined by setting slide rule at the desired nominal OD for any standard ring. For nonstandard rings, chart also gives complete data on how to calculate correct installation dimensions. Write on company letterhead to Advanced Products Co., 59 Broadway, North Haven, Conn.



RIVNUT FASTENERS LICK VIBRATION PROBLEMS ON TRAIN TELEPHONES. These portable carrier telephones, used on rapid transit cars, have to withstand frequent handling and train vibration and shock. The rugged construction includes use of RIVNUTS for vibration-resistant fastening. The manufacturer, Femco, Inc., of Irwin, Pennsylvania, also cut costs with RIVNUTS by speeding up assembly of components. RIVNUTS are the only blind fasteners with internal threads—provide strong nutplates in thin-gage metal. For data booklet showing applications, sizes, and tool data, write Dept. MD-3A, B.F.Goodrich Aviation Products, a division of The B.F.Goodrich Company, Akron, Ohio.

B.F.Goodrich RIVNUTS

Circle 460 on Page 19

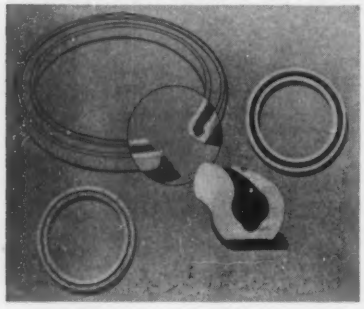
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Teflon O-Rings

contain an internal expander

Tec-Rings incorporate either a stainless-steel or synthetic-rubber internal expander, depending upon the intended environment. Expander maintains a continuous mechanical force against the sealing surface, overcoming the tendency of the material to shrink away from sealing surfaces when temperatures are reduced. Rings need no adjustment, and range in size from $\frac{1}{8}$ to 15 in.



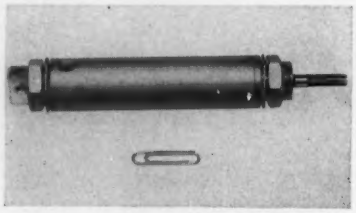
ID. Recommended uses include hydraulic applications involving high or low temperatures, extrusion due to high pressure, friction, nonlubricating liquids, gases, and corrosive fluids. **Tanner Engineering Co.**, 1003 Santa Fe Ave., Los Angeles 21, Calif.

Circle 741 on Page 19

Miniature Hydraulic Cylinder

in single and double-acting units

Compact, heavy-duty, $\frac{7}{8}$-in. bore miniature cylinder is available for maximum working pressure of 250 psi air and 2500 psi hydraulic. Cylinder is furnished in 1-in. stroke, spring-return model, and 1, 2, 3, 5, 7, and 9-in. double-acting models. Power factor of 0.60 gives 60 lb force at 100 psi and 1500 lb force at 2500 psi. Cylinders stud mount



front or rear, clevis mount rear, or foot mount with nuts and lock washers. Ports are standard $\frac{1}{8}$ in. NPT on cylinder side. **Clippard Instrument Laboratory Inc.**, 7390-P Colerain Rd., Cincinnati 39, Ohio.

Circle 742 on Page 19

Precision Knobs and Hubs

offers extreme accuracy for dial mounting

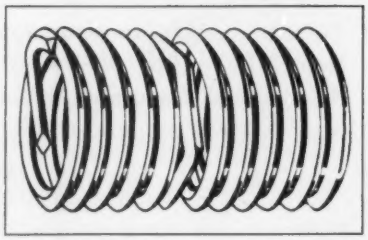
Manufactured of 24 ST aluminum, precision knobs and hubs are supplied with polished surface or black enamel finish. Concentricity within 0.0015 in. T.I.R. between shaft hole and step diameter offers accuracy for dial mounting. They are furnished with two stainless-steel set screws. **Ackerman Engravers**, 458 Broadway, New York, N. Y.

Circle 743 on Page 19

Self-Locking Insert

for applications to 1200 F

Self-locking insert of Inconel X wire attains its locking effect from a "grip coil" midway in its length. Coil is polygonal in shape rather than circular. As bolt is screwed



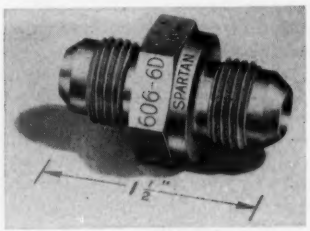
through threads of insert, flat chords of grip coil are forced to conform to the usual thread shape. Insert is available for fastening applications to 1200 F, and should be used with silver-plated 0.003-in. undersize bolts. UNF sizes from 10-32 through $\frac{1}{2}$-20 are available, with immediate delivery in $\frac{1}{4}$-28 series in $1\frac{1}{2}$ and 2-in. diam lengths. **Heli-Coil Corp.**, Danbury, Conn.

Circle 744 on Page 19

Miniature Check Valve

for systems with pressures not exceeding 60 psi

No. 606 miniature check valve has a total pressure drop of less than 1 psi at rated flows. Maximum cracking pressure is 8 in. of water, and total pressure drop does not exceed 20 in. of water at rated flow. Designed for aircraft fuel systems and other applications where operating pressures do not exceed 60 psi, valve is compatible with 90



per cent hydrogen peroxide, nitric acids, and other fuels. Available in tube sizes from $\frac{1}{4}$ to $1\frac{1}{4}$ in., it meets specification MIL-V-7899. **Sparton Mfg Corp.**, 445 Saw Mill River Rd., Yonkers, N. Y.

Circle 745 on Page 19

Precision Differentials

in shaft and hollow-shaft types

Line of precision differentials offers complete range of sizes, lost motions,

Another pump problem . . . solved by **TUTHILL**

TUTHILL

pump-motor combinations add to precision, dependability of GPE electrohydraulic valve actuators

The Model 684 heavy-duty Electrohydraulic Valve Actuators produced by GPE Controls are used to position valves in response to low level DC input signals from electronic controllers, manual stations or flow or pressure transducers. Often used outdoors, they must be rugged . . . and their precision and dependability must be beyond question.

A vital component of these precision controllers is the Tuthill Series 48 close-coupled electric motor and hydraulic pump combination. Chosen primarily for their dependability, the compactness (5⅞"x11 15/16"), and light weight (21 pounds) of these combinations enabled them to fit into GPE Controls' design without assembly difficulties.

Complete close-coupled selection

The Series 48 units are only one of a complete selection of Tuthill close-coupled combinations provided in three general series with capacities up to 50 gpm, for pressures to 500 psi. All units are particularly designed for applications where space is at a premium. Elimination of couplings, bases and adapters results in significant savings. Reduced weight means lower shipping costs . . . and their compactness simplifies assembly operations and lowers production costs.

Over 800 models

These close-coupled pump and motor units are but a small part of Tuthill's complete line of over 800 different standard models. In addition, Tuthill's experienced staff of application engineers will work with you in designing a special unit to precisely meet all the requirements of your particular application . . . "fit the pump to the problem."

Write today for Catalog 100 which describes the complete Tuthill line. Or, better yet, send drawings or other information on your pump application so that our engineers can indicate how Tuthill may be able to provide savings in your particular operation.

Tuthill manufactures a complete line of positive displacement rotary pumps in capacities from 1/3 to 200 GPM; for pressures to 1500 PSI; speeds to 3600 RPM.

PUMPS FOR YOUR PURPOSE

TUTHILL PUMP COMPANY

943 East 95th Street, Chicago 19, Illinois

Circle 461 on Page 19

800 to 1 hp favorites for quiet operation, low maintenance and long-life service . . .

From the case of the A. O. Smith Motor Man — a complete stable of integrals that include single-phase models (1-5 hp) or polyphase (1-800 hp). Also a team of fractional-hp motors. All are sure bets to give top performance over the long, long haul.

And there's an A. O. Smith Motor Man near you — chomping at the bit to give you 24-hour action on all parts and service orders.

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ELECTRIC MOTORS

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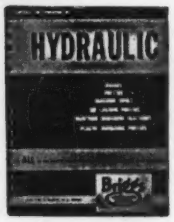
A. O. SMITH INTERNATIONAL, S.A. Milwaukee 1, Wisconsin, U.S.A.

Circle 462 on Page 19

BRIGGS OFFERS YOU, FREE, A 12 PAGE MANUAL ON HYDRAULIC FLUID CIRCUITS AND HYDRAULIC OIL FILTRATION

HERE is a big 8½" x 11", file size, 12 page, fully illustrated booklet. It's brimful of technical data and drawings that every designer and operating engineer will want to read or keep for ready reference. Write for your copy. No obligation.



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FILTER/SEPARATORS
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THE BRIGGS FILTRATION CO., DEPT. 368, WASHINGTON 16, D. C.

YES AT NO COST OR OBLIGATION, SEND ME THE ABOVE HYDRAULIC MANUAL

NAME .....

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Circle 463 on Page 19

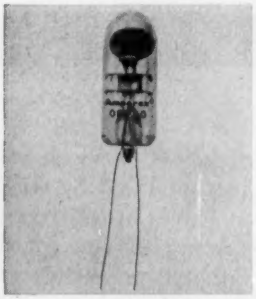
and end gears, as well as a selection of various dimensions between end gears. The end gears are available in both aluminum and stainless steel with consecutive tooth sizes. Differentials are available in both shaft and hollow-shaft types of 3/32, 1/8, 3/16 and 1/4-in. shaft sizes, with one and two pinions. **Dept. D, Atlas Precison Products Co.**, Castor & Kensington Avenues, Philadelphia 24, Pa.

Circle 746 on Page 19

Cadmium-Sulfide Cell

is 0.63 in. in diam and 1.42 in. long

ORP 50 light-sensitive, cadmium-sulfide cell is both top and side-sensitive—the cadmium-sulfide area is mounted at a 45-deg angle. Hermetically sealed and of rugged, all-glass construction, cell is used for



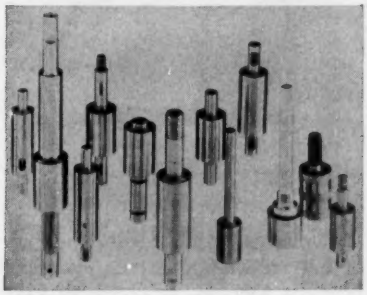
both industrial and entertainment applications. Pigtail leads save space and provide versatility in mounting. Unit is 0.63-in. diam by 1.42 in. long. Maximum dissipation is 250 mw, and average cell current is 10 ma. **Semiconductor & Special Purpose Tube Div., Amperex Electronic Corp.**, 230 Duffy Ave., Hicksville, L. I., N. Y.

Circle 747 on Page 19

Shaft Bearings

for shaft diameters of 3/8, 1/2, 5/8 and 3/4 in.

Some 20 new shaft-bearing configurations include waterproof and heavy-duty units. All bearings have lifetime Permawick lubrication, recirculatory oiling system, and life expectancy of 20,000 hr. Bearings are quiet in operation and are highly resistant to moisture and other atmospheric contaminants.



Configurations are designed around shafts with nominal diameters of 3/8, 1/2, 5/8, and 3/4 in. with a variety of ODs and special shaft contours. **Tann Bearing Co., Div., Tann Corp.**, 3750 E. Outer Drive, Detroit 34, Mich.

Circle 748 on Page 19

Magnet Wire

has exceptional dielectric strength

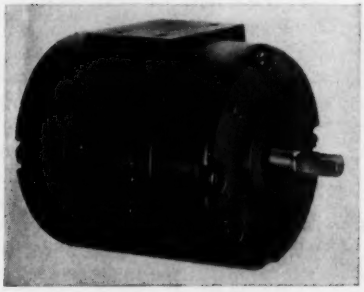
New magnet wire is film coated with Type ML polymer. Rated for Class H temperature service or better, wire has shown a life in excess of 10,000 hr at 240 C. Cut-through resistance is in excess of 400 C. Solvent resistance is excellent, including resistance to synthetic transformer oils and mineral oils. Dielectric strength is 3400 v per mil dry, 1900 v per mil wet. Wire is available in sizes from AWG 20 through 44. **Tensolite Insulated Wire Co. Inc.**, West Main St., Tarrytown, N. Y.

Circle 749 on Page 19

AC Motors

for military and industrial uses

G-Frame ac motors are available with horsepower ratings from 1/400 to 1/4. Induction or hysteresis-synchronous types are furnished, either



"Jeep" Industrial Engines power Hobart welders.

COMPACT ENGINE WITH A RUGGED HEART

'Jeep' 4L
INDUSTRIAL ENGINE

It measures 24.81" from fan to flywheel, yet pulls with the might of 60 horses. Tough and proven for welder, compressor, sprayer, lift trucks and others. Customer accepted, with a name that is respected world wide.

Many "extras" for long life are *standard* with the 'Jeep'-4L Industrial Engine. Positive valve rotators, positive crankcase ventilation, eatonite or stellite exhaust valves, and more . . . at no extra cost.

Send for catalog giving details and power curves.
LP Gas and Marine Conversion Kits available.

KAISER WILLYS MOTORS
WILLYS MOTORS, INC.
INDUSTRIAL ENGINES DEPT.
TOLEDO, OHIO

Manufacturers of 4 and 6 Cylinder 'Jeep' Industrial Engines

Circle 464 on Page 19

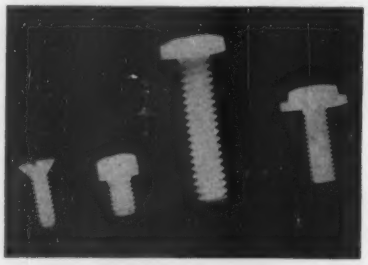
self-cooled or totally enclosed, finned or plain. Suitable for both military and industrial applications, units operate on 60 cps. Either one or three-phase, two or four-pole speeds are available. Ambient temperature range is −55 to +125 C. Motors are available with or without mounting base. **Air Marine Motors Inc.**, Bayview Ave., Amityville, L. I., N. Y.

Circle 750 on Page 19

Molded Delrin Screws

are available in six head types

New fasteners are molded of Delrin to close tolerances. Delrin screws possess electrical insulation properties, high tensile strength, rigidity, and resistance to deformation, and dimensional stability over a wide range of environmental conditions. Screws offer low water absorption and low coefficient of friction. They resist corrosive fluids, such as gasoline, carbon tetrachloride, hydraulic fluids, and oils. Screws are available in six head types, in six point types, and in headless set screws. Threads range from 0-80 to ¼-20. **Gries Reproducer Corp.**, New Rochelle, N. Y.

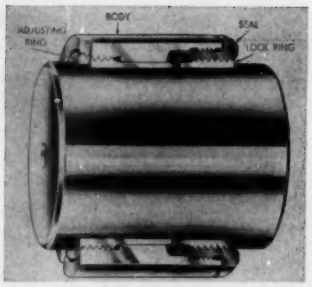


Circle 751 on Page 19

All-Metal Seal

for temperatures to 530 F and pressures to 6000 psi

All-metal seal for dynamic applications handles hydraulic pressure and heat under adverse conditions encountered by missiles and supersonic aircraft. Seal performs satisfactorily at temperatures to 530 F and pressures to 6000 psi. It does not require close tolerances, is self-compensating for reasonable misalignment and side loads, and has a low break-out force. **Aviation Products Div., B. F. Goodrich Co.**, Akron, Ohio.



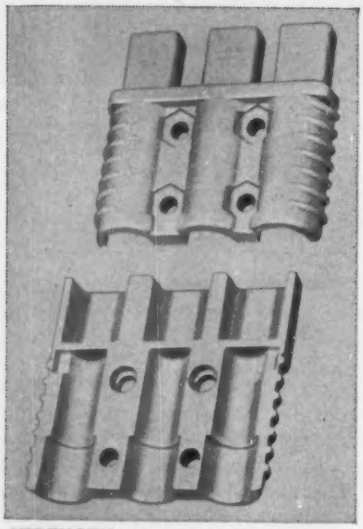
Circle 752 on Page 19

PVC Ball Valves

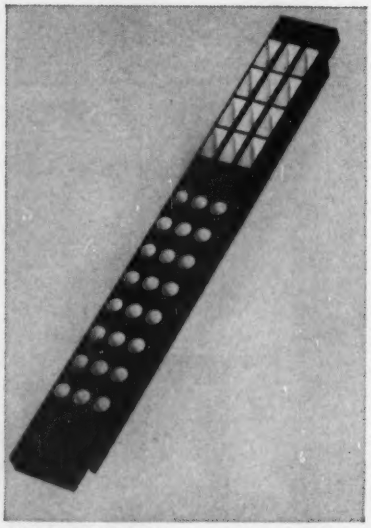
assure positive shutoff at pressures to 125 psi

Originally produced in ½, ¾ and 1-in. sizes, PVC ball valves now include 1½, 2, and 3-in. units. Valves assure positive shutoff at pressures to 125 psi with only one-quarter turn of snap-on handle. Useable at temperatures to 140 F, they are molded of tough, unplasticised, Type I polyvinyl chloride. Offering resistance to most corrosives, valves

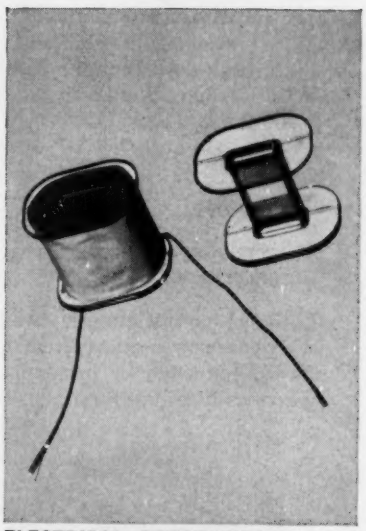
G-E LEXAN® POLYCAR



STRENGTH LEXAN resin has an impact strength of more than 12 foot-pounds per inch of notch — higher than any other plastic! This toughness, plus heat resistance and good electrical properties, make LEXAN resin an outstanding choice for 3-pole connectors used in rugged service on electric trucks.



HEAT STABILITY Lampholder terminal block is used inside electronic equipment where heat is difficult to dissipate. LEXAN polycarbonate resin replaced another thermoplastic which melted under severe thermal conditions. LEXAN has a heat distortion point as high as 290°F. Also keeps high strength in sub-zero cold.



ELECTRICAL PROPERTIES A good dielectric, LEXAN resin is non-corrosive even when used with very fine Class F magnet wire. Coil forms must not distort at temperatures above 200°F under stresses caused by tightly wound wire. LEXAN resin provides high heat distortion temperatures under load.

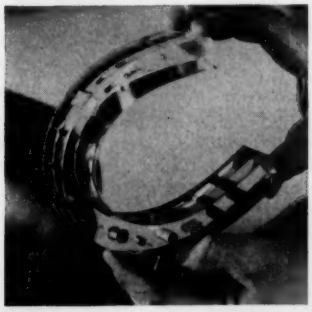
maintain high dimensional stability. Teflon seats and neoprene O-rings provide leaktight seals. Coupling-like assembly permits each half of the valve to be fitted to pipe ends and then reassembled. **Hoke Inc.**, 1 Tenakill Park, Cresskill, N. Y.

Circle 753 on Page 19

Silicone-Resin Encapsulant

is tough, flexible, and transparent

Sylgard 182 silicone encapsulating material permits visual inspection of circuits and components within potted, embedded, or encapsulated assemblies. Applied as an almost colorless liquid, after blending with curing agent, material cures in place, even in totally confined enclosures, to form a transparent mass having outstanding dielectric properties, good moisture resistance, flexibility, and toughness. Curing time for the resin can be varied by changing the curing temperature. Cured resin can be cut away with a sharp knife so that defective components can be repaired or replaced. New resin poured over the repaired area adheres to the original material, restoring the encapsulant to the original condition. **Dow Corning Corp.**, Midland, Mich.

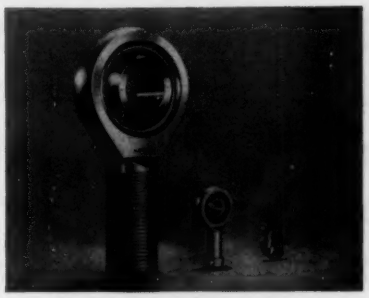


Circle 754 on Page 19

Rod Ends

for use in a variety of mechanisms

Large-size rod ends, control-rod assemblies, and high-angle rod ends with studs are now available. Bearings are applied in a wide variety of mechanisms, usually in linkage systems where misalignment must be accommodated. Construction features of Alinabal units permit sustained rotational operation. Bearings feature a precision-ground, through-hardened steel race around an oil-impregnated, sintered metal ball. **Split Ballbearing Div., Miniature Precision Bearings Inc.**, Lebanon, N. H.



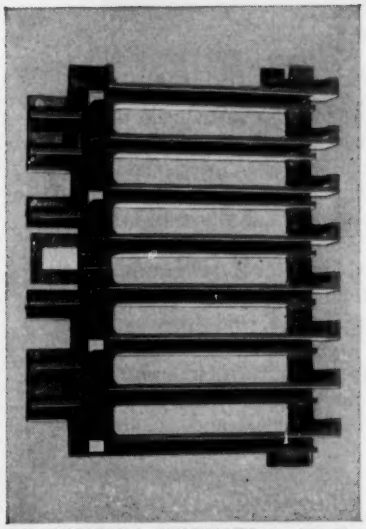
Circle 755 on Page 19

Coaxial Connector

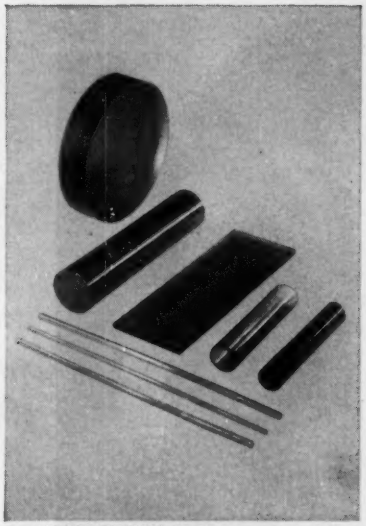
subminiature unit weighs only 5 grams

Nu-Lok connector, typical of Series 1100, is designed for use with 50-ohm RG-196/U coaxial cable. In-

BONATE RESIN TOUGHEST OF PLASTICS!



DIMENSIONAL STABILITY Card Guide for business machines is molded to close tolerances . . . must undergo minimum change in dimensions during service. Parts show excellent dimensional stability under moist and high temperature conditions. LEXAN resin meets self-extinguishing requirement.



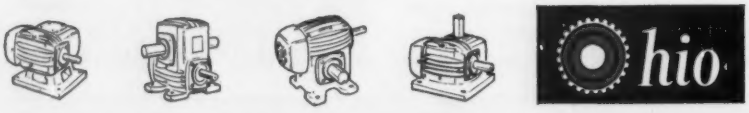
TRANSPARENCY Stock shapes and film of LEXAN polycarbonate resin have excellent transparency. Bar stock is easily machined; film can be thermoformed, heat-sealed and solvent-sealed. Combination of clarity, toughness and malleability gives LEXAN resin the design capabilities of a transparent metal!

LEXAN OPENS UP NEW OPPORTUNITIES... Even before LEXAN entered large-scale production, manufacturers, impressed by its exceptional properties, developed and field tested over 300 applications. G.E. participated in these developments. With the opening of new G-E facilities capable of producing millions of pounds of LEXAN per year, the price of this versatile thermoplastic has dropped dramatically – over 40% in a single year. This fact alone has brought many new products within the range of feasibility. Can you afford to overlook the opportunities presented by LEXAN? Send for details on price, properties, applications and G-E's technical assistance program today! General Electric, Chemical Materials Department, Section MD-31, Pittsfield, Mass.

LEXAN®
Polycarbonate Resin
GENERAL ELECTRIC

Circle 465 on Page 19

Get 80% more capacity in 25% less space with ⚙HI⚙ LINE... industry's most modern line of speed reducers. ⚙HI⚙ **LINE** reducers are available in more than 350 standard models and sizes—available for fast delivery from local stocks in 63 strategic points throughout the country. Write for a complete 246 page catalog: Ohio Gear Company, **1302** E. 179th St., Cleveland 10, Ohio



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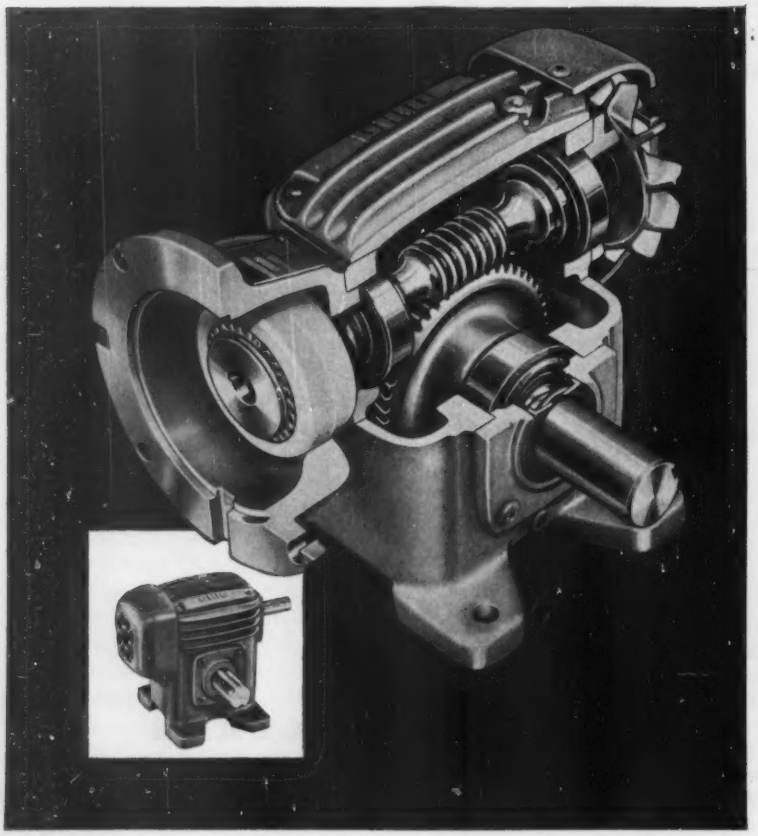
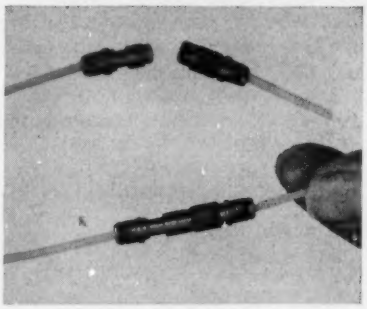




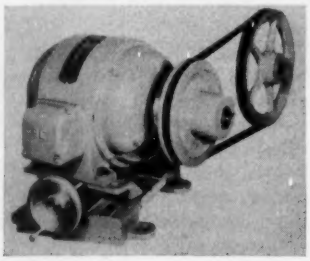
stantly engaging or releasing with only a slight movement of the locking device, the quick-disconnect coaxial connector measures $\frac{1}{4} \times 1\frac{3}{8}$ in. and weighs 5 grams. Captured-bayonet locking mechanism is positive acting and withstands vibration without damage or separation. When mated, connector resists a sustained force of over 45 lb. **Nu-Line Industries Inc.**, 1015 S. Sixth St., Minneapolis 4, Minn.

Circle 756 on Page 19

Adjustable Motor Bases

for use with spring-loaded sheaves

Adjustable motor bases are available in two models, MB-11 and MB-12. They can be used with standard M-type spring-loaded sheaves to provide a complete drive for low-speed applications in horsepower capacities from $\frac{3}{4}$ to 10. Designed for use with Speed Selector sheaves, bases permit employment of other sheaves having equal linear motion of both faces. Speed variation is accomplished by a simple hand-wheel control as illustrated, and remote control can also be provided. Speed indicator and comparator scale facilitate setting the drive at any desired speed, and screw-type control is self-locking. Design of the bases permits their use in an angular position to maintain proper belt alignment and assure long



Circle 466 on Page 19

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put HEINZE in your designs

HEINZE UNIVERSAL MOTORS

are VERSATILE

An endless variety of modifications are available on Heinze Universal Motors, such as stainless steel shaft . . . special cuts on shafts such as worms, pinions, screw threads, cross holes, flats, etc. . . . double shaft extension . . . cord sets . . . inline switches on cord sets . . . ventilated cases . . . fungus proofing . . . various type leads . . . choice of color.

In addition, Heinze Universal Motors are rugged to withstand tough applications, compact to fit limited space, have high starting and running torque, variety of mounting arrangements, are uniform in quality, keyed to high production, and are competitively priced.

Standard voltage rating is 115V AC/DC but motors are supplied for other voltages.

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Circle 468 on Page 19

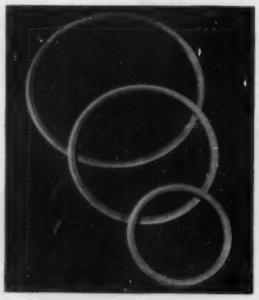
belt life. Bases are cast iron. Speed Selector Inc., P. O. Box 312, Chagrin Falls, Ohio.

Circle 757 on Page 19

Pressure-Actuated Seal

for temperatures from −450 to +500 F

Pneuflex pressure-actuated seal requires only normal machined finishes on mating flange and component surfaces. Unit meets high-pressure and extreme-temperature requirements of system components in missiles and high-performance aircraft where temperatures range from −450 to +500 F at pressures



to 5000 psi. Seal is a flexible metallic ring with protruding sealing edges coated with a soft, resilient material. Spring load forces soft coating to flow into minute scratches and irregularities on the mating surfaces of the flange or component, producing an initial seal. Effectiveness of the seal increases as the pressure load increases. Seal is normally fabricated from aluminum alloy and coated with Teflon for low-temperature applications. Stainless steel, Monel, and Inconel steels coated with copper, gold, or silver are used for high-temperature applications. Del Mfg. Div., Arrowhead-Puritas Waters Inc., 1584 E. 20th St., Los Angeles, Calif.

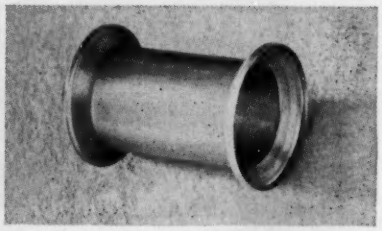
Circle 758 on Page 19

Pushbutton Station

of all-rubber, corrosionproof construction

Heavy-duty pushbutton station, Flexitite Switch, is recommended for any two-station pushbutton application. It is of corrosionproof, all-rubber, weather-sealed construction. Switch fits all standard FS and FD

"know-how" pays off in Tubular Part Fabrication



• UNIFORM TUBES' know-how solved the problem of right temper and grain size needed to bell the ends of this nickel, electronic tube part without thinning the wall. Their special tooling permitted close concentricity and dimensional tolerances.

• Mass-producing this light meter pointer required unique tooling skills and extreme precision of aluminum tubing stock. Fabrication involves coining and bending to exact thicknesses and angles in three planes while maintaining perfect centerline parallelism.

• To make this missile component fit perfectly, UNIFORM TUBES had to bend .250″ O.D. x .035″ wall stainless steel tubing, maintaining end roundness and holding O.D. variations to less than .002″ despite the complication of cutting one end along the radius of a bend.

Tell us your fine seamless tubing or tubular part needs, and save time and expense.

UNIFORM TUBES, INC.
COLLEGEVILLE 2, PA.
HUxley 9-7276 TWX-CGVL 1044

Circle 469 on Page 19

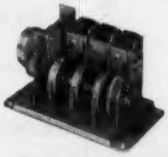
THE SPACE JOURNEY THAT BEGAN WITH AN

INDUSTRIAL TIMER

INTERVAL TIMERS

TIME DELAY TIMERS

RUNNING TIME METERS



RECYCLING TIMERS

The first space shot with living creatures that returned alive is now history—a significant milestone in the conquest of space.

The two monkeys, placed aboard the rockets to help scientists gather data on the probable effects of space travel on man, received unique training on the apparatus pictured above.

They were conditioned to manipulate the lever in response to timed stimuli, governed by a 4-unit tandem of Interval Timers by Industrial Timer Corporation.

This is not the first time our products have been used in medical and psychological projects. However, they are more commonly found where precise, reliable timing of industrial processes is vital.

Send for literature describing the comprehensive line of Industrial Timer Corporation Timers for every industrial application.

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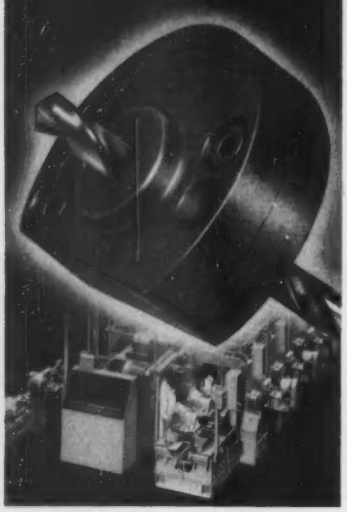
1404 McCarter Highway, Newark 4, New Jersey

Circle 470 on Page 19

NEW BROKEN TOOL DETECTOR



"Detect-A-Tool" is the new space saving solution to the problem of detecting tool breakage on automatic machine tools and transfer lines.

Expensive probe stations are eliminated as well as their attendant maintenance cost and floor space requirements, as the "Detect-A-Tool" is mounted on the work station itself.

Since the tools are checked each time they are used, tool failure is detected immediately and scrap losses from tool failures are eliminated.

"Detect-A-Tool" equipment can be easily installed on both old and new equipment. There are no complex moving parts to wear or get out of order, and little or no maintenance is required. Coolants, oils, or chips will not affect operation in any way.

"Detect-A-Tool" units are presently available for tools having effective diameters from 3/32" to 3/4".

This equipment features the same rugged construction and conservative electrical design that typifies all "MEK" products.

Complete "Detect-A-Tool" descriptive literature will be sent on request.

Manufacturers of
- *Electronic and Magnetic Controls*
- *Motor Control Centers*
- *Fabricated Electrical Enclosures*

MEK
Machinery Electrification, Inc.
Hudson St., Northboro, Mass.

Circle 471 on Page 19

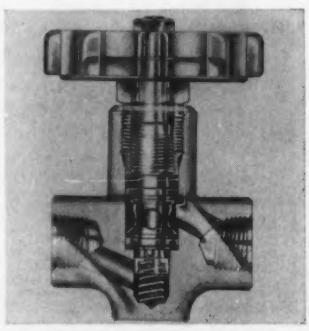
boxes, and flush mounting can be achieved on metal surfaces. It incorporates micro-type, one or two-pole switches with normaly open and/or normally closed contacts. Each switch package includes choice of station legend plates and snap-in, oversize buttons. Molded-rubber construction provides safety, long life, and corrosionfree operation. **Electrical Products Div., Joy Mfg. Co.**, 1201 Macklind Ave., St. Louis 10, Mo.

Circle 759 on Page 19

Shutoff Valve

for use in severe corrosive service

Series 920-T shutoff valve is rated to 6000 psi operating pressure in liquid or gaseous service. Constructed entirely of 303 stainless steel with Teflon seals, it is intended for use in severe corrosive conditions. Internal design features standard Teflon V-packers which seat against a Belleville washer. Springlike flexibility of the washer maintains a constant sealing pressure on the V-packers. Floating sleeve rises to protect V-packers from fluid flow when valve is open. Valve need not be removed from the line for replacement of Teflon seals. Stem threads are removed from the flow path to permit lifetime lubrication and to prevent flow from being con-



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Circle 472 on Page 19

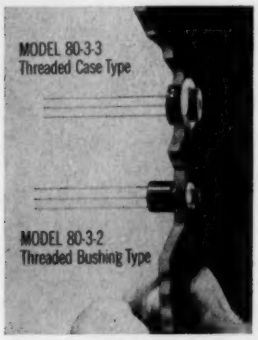
taminated by the lubricant. Double-tapered stem design provides gradual throttling when valve is closed. **Circle Seal Products Co.**, 2181 E. Foothill Blvd., Pasadena, Calif.

Circle 760 on Page 19

Trimmer Potentiometers

are furnished in panel-mounting types

Two ultraminiature trimmer potentiometers have resistance to 20,000 ohms. Model 80-3-2 has 1/3-in. diam and 10-32 threaded bushing for panel mounting. Model 80-3-3 has a ⅜-in. diam x 32 threaded case and mounts within panel with little projection front or rear. Both single-turn models have machined



aluminum, sealed cases. Approximately one-fourth the size of rectangular trimmers, Model 80 offers greater resolution because its resistance element is nearly twice as long. Resistance range is 50 to 20,000 phms, and tolerance is ±5.0 per cent. Power rating is 1 w at 50 C. Unit withstands 50 g shock and 30 g vibration to 2000 cps. **Spectrol Electronics Corp.**, 1704 S. Del Mar Ave., San Gabriel, Calif.

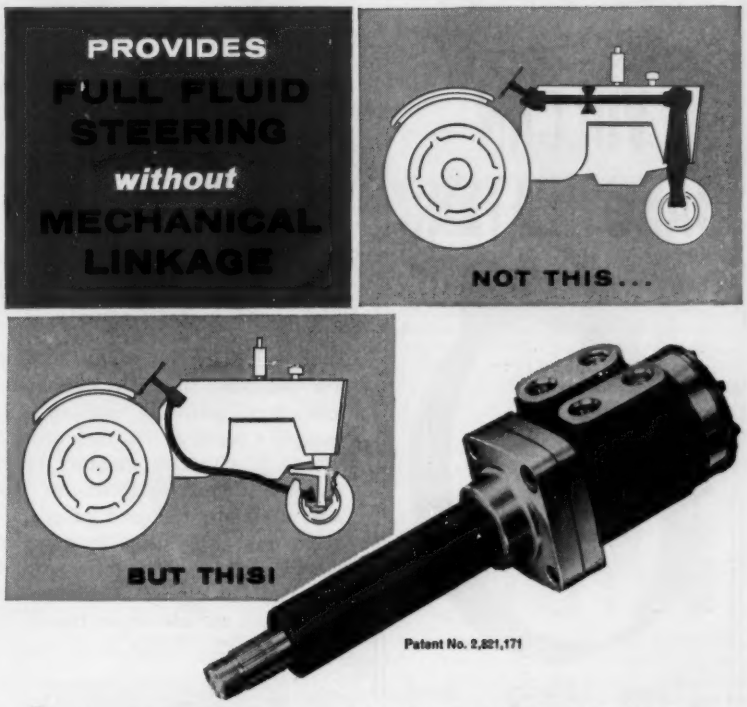
Circle 761 on Page 19

Ball Bearing

has excellent resistance to corrosion

Haynes Alloy 25 ball bearing has high hardness (Rockwell C 50) and ability to operate at temperatures to 1000 F. These properties, in addition to corrosion resistance, make the bearing adaptable for the food-processing, high-temperature valve, and photo-processing industries, in addition to other applications. Deep-

Char-Lynn "ORBITROL"®



The New **ORBITROL is a completely integrated fluid steering control** system that eliminates steering gear boxes and mechanical linkages to the axle.

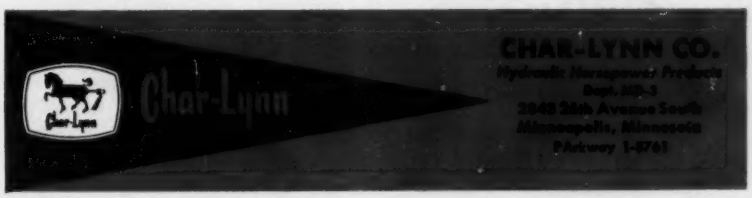
Only **ORBITROL provides remote rotary servo control** with sensory direction and delivery measurement within the same unit . . . the **ideal** concept for modern self-propelled vehicles.

ORBITROL also features integral manual steering for use in emergency or "engine-off" conditions . . .

When live hydraulic power is not available the ORBITROL automatically becomes a rotary hand pump and directs fluid to move the actuator in either direction when the steering wheel is rotated.

The ORBITROL is ideally suited for controlling conventional steering systems, multiple axles and dual control installations.

Contact CHAR-LYNN today . . . our engineers will be pleased to submit recommendations relative to your particular application or needs.



Circle 473 on Page 19

VULCAN BAND HEATERS

Vulcan Cylindrical Band Heaters are especially designed for plastic molding and extruding machines, tanks, pipelines, autoclaves, and similar applications. An aluminized steel sheath, together with a special-alloy, tight-gripping clamping band, assures long life. Heating element is precision spaced for uniform heat.

A wide range of diameters (from 1⅝″ to 18″ or more) is available to fit most assemblies. Special widths, sizes, and materials can be engineered to individual requirements.

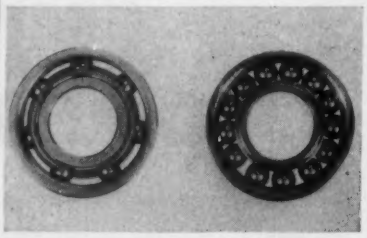
Vulcan Band Heaters are a modification of the popular Strip Heaters which efficiently heat practically any surface. *Write for catalog and prices.*

VULCAN

Versatility in Electric Heating

VULCAN ELECTRIC COMPANY, Danvers, Mass.

Circle 474 on Page 19



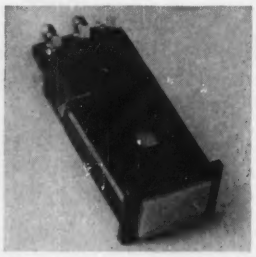
groove, full-complement, no loading-slot bearings are 1⅛ in.-OD by ½-in. bore. **Bearing Div., Industrial Tectonics Inc.,** 18301 Santa Fe Ave., Compton, Calif.

Circle 762 on Page 19

Pushbutton Switches

of one-piece construction

Snap-action pushbutton switches are available in both illuminated and nonilluminated versions. Of one-piece construction, they are furnished in either momentary or alternate-action configurations. Design eliminates the need for external accessories. Mounting arrangement allows rigid mounting in virtually any panel thickness. Available configurations include one or two SPDT switches with ratings of 5 amp at



220 v ac and 0.25 amp at 220 v dc. **Truco Engineering Co.,** 195 W. Main St., Avon, Conn.

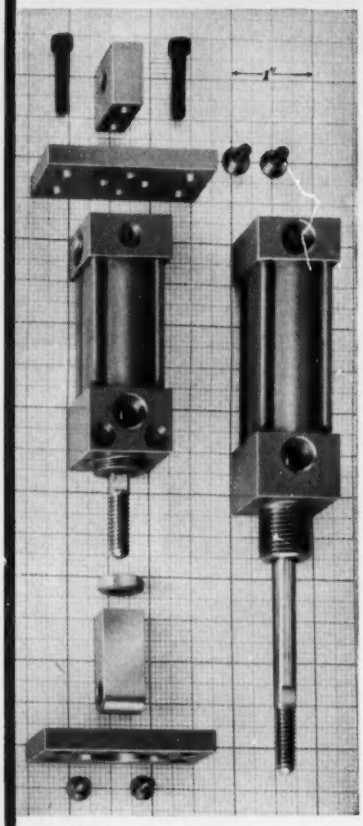
Circle 763 on Page 19

DC Motor

is nominally, rated at ½ hp, 5000 rpm, 24 v

New 4-in. diam dc motor is designed to supply drive for battery-operated equipment. Four-lead, series-wound motor is nominally rated at ½ hp, 5000 rpm, 24 v dc. Normally applied through belt, chain, or gear drives, motor speed can be varied by adding resistance to the motor circuit or by switching of battery voltages. Motor is

HOW SMALL do you want 'em?



Hannifin offers new "Midget-Air" 200 psi cylinders in ¾", 1" and 1⅛" bores, double-acting or spring-return. Two basic models, "universal" and "nose-mounting." Universal models come drilled and tapped for mounting, or for use with any combination of the mounting attachments pictured. Delivery is off-shelf in standard strokes, shipment in ten days to specified stroke lengths. Want dimensions and prices? Write:

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SAVE TIME, AIR, MONEY

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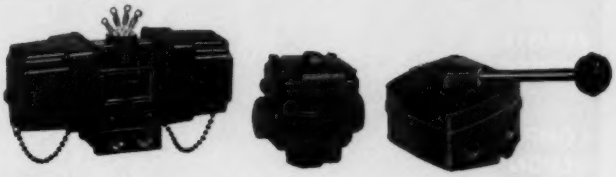
Your pneumatic system shapes up faster at the design stage when one man can discuss with you every component you'll need. But have you realized how much your Parker-Hannifin man can save you in money and air?

Just for instance . . . your valves don't have to be ¾" just because the cylinder size you select comes with ¾" ports. Your Parker-Hannifin man chooses valve types and sizes to suit the air flow you'll need. He'll show you too, how pressure control saves money and air, how a smaller lubricator is often a more efficient lubricator, and other money saving ideas. Then he'll show you ways to "tube up" and "hose up" a leakproof pneumatic system quicker, neater and at lower cost.

Call your nearest Parker-Hannifin sales office, or write direct for complete information.

3180-PH-a

Low friction, long packing life are money-saving features of the Hannifin Series "A" pneumatic cylinder, available in a full range of mounting styles and from 1½" to 14" bore, strokes to 20 feet. Hannifin cylinder application data and charts make selecting the right Series "A" cylinder easy. Get yours from your Parker-Hannifin man.



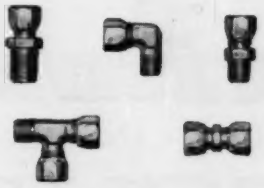
DUAL SOLENOID, 4-WAY

PRESSURE, 3-WAY

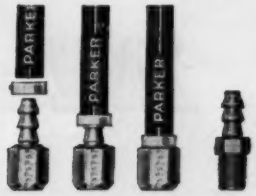
HAND, 4-WAY

CAM, 3-WAY

Use flow factors as money-savers—your Parker-Hannifin man can show you how. They help you to avoid "oversizing" your valves. Hannifin's new Valve Finder gives "C_V" ratings for every valve in the line, makes it possible for you to take full advantage of the extra air-flow capacity in Hannifin air valves. Get your copy today.

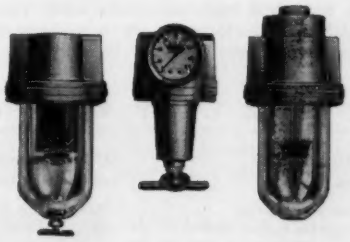


Pneumatic systems tube up fast with Parker "Intru-lok" tube fittings. Use them with copper, nylon or "Parker-POL" polyethylene tubing. Just insert the tube and tighten the nut for a leakproof "bite-type" joint.



Another time-saver is "Push-lok", the Parker hose-and-hose-fittings combination for pressures to 250 psi. No tools needed. Just push this hose on these hose fittings. They won't blow off, ever, not at twice 250 psi.

One air line connection installs the Hannifin Air Motor . . . an integral solenoid valve controlling a fast, rugged double-acting air cylinder. Built-in speed controls adjust piston speed in either or both directions.



You will save both air and money with Hannifin "Crown" air line filters, pressure regulators and lubricators. Let your Parker-Hannifin man show you how they pay for themselves by making it possible to get all the air flow you need at the exact pressure that will best do the job. "Crown" filters and lubricators will bring further savings through reduced equipment maintenance.

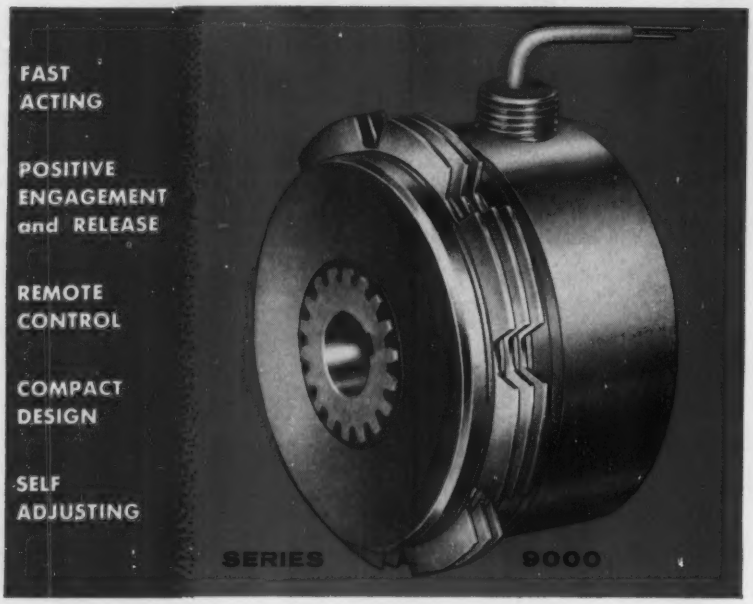
Parker FITTINGS AND HOSE DIVISION
17325 Euclid Avenue • Cleveland 12, Ohio

HANNIFIN COMPANY
A DIVISION
515 South Wolf Road • Des Plaines, Illinois

PNEUMATIC AND HYDRAULIC SYSTEM COMPONENTS

EUROPEAN DIVISION • PARKER-HANNIFIN N.V. • SCHIPHOL • THE NETHERLANDS

IDEAL FOR AUTOMATED MACHINES



Maxitorq
ELECTRIC
CLUTCHES and BRAKES

Incorporating advanced design principles proved through years of service, the MAXITORQ Electric Clutch is well adapted to all types of machine drives. Simple in design . . . built to machine tool standards . . . requires no adjustments, can be used either as a clutch or brake. Disc separators not only separate discs, but also break up residual magnetism and result in extremely fast, positive action with no drag or heating in neutral. There are few moving parts. Electrical operating unit remains stationary — hence, no troublesome slip rings, brushes, or difficult wiring problems. Operation is on standard 100 V a.c. Other voltages on special order.

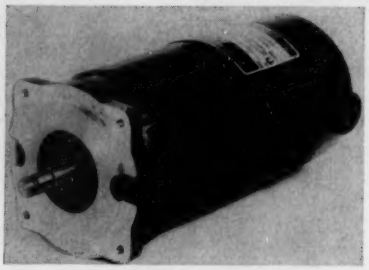
If you have a clutch or brake application where you are looking for NEW and IMPROVED performance, we invite you to bring the problem to us. Phone, wire, or write Dept. MD for Bulletin No. 90.

SPECIAL FEATURES

- Engaged entirely by magnetic flux.
- Operate either on-off or by varying voltage for torque control.
- NO troublesome slip rings or brushes.
- NO levers, cams, or other highly stressed mechanical parts.
- Operation is not dependent upon rotation.
- Finished complete, assembled, and ready to install on shaft.

THE CARLYLE JOHNSON MACHINE CO.
MANCHESTER, CONN.

ICJ61



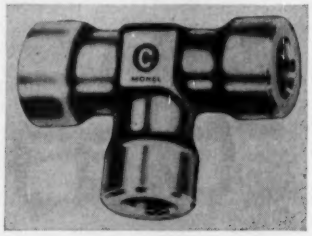
reversible. Weighing approximately 13 lb, open, ball-bearing motor incorporates a rabbetted flange with four ¼-20NC2B drilled and tapped holes for end-mounting. It can also be supplied with solid base. **General Electric Co.**, Schenectady 5, N. Y.

Circle 764 on Page 19

Weld Fittings

are leakproof under vibration and shock

Socket Weld tube fittings are available in aluminum, brass, Inconel, nickel, stainless steel, and steel. In addition to a standard line in sizes from ⅛ through 1 in. OD, fittings are also produced in custom shapes, sizes, and materials. Fittings are designed for applications involving problems of corrosion, pressure, and temperature, and provide leakproof performance under



vibration and shock. **Cajon Machine Co.**, 902 E. 140th St., Cleveland 10, Ohio.

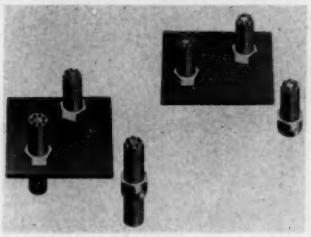
Circle 765 on Page 19

Miniature Connectors

accept wires of 0.01 to 0.22-in. diam

Insulated feedthrough and standoff component connectors offer high tie-point density in small size. Designed for miniature assemblies, connectors are 0.25 in. high off the board, and 0.190 in. OD. They hold

seven microminiature sockets equally spaced on a 0.120-in. diam circle. Using the connectors, tie points can be mounted and tied together by simple insertion means, and components or jumper wires can be changed easily. Whole circuits can be switched around in characteristic or operational function without soldering. Units accept wires of 0.010 to 0.022 in. diam. Connectors can be mounted on fixed or known grid patterns, permitting automatic insertion of components. Connector section is insulated from case, so that units can be mounted on



metal chassis or base plates to make up submodules. **Omega Precision Inc.**, 757 N. Coney Ave., Azusa, Calif.

Circle 766 on Page 19

Flow-Control Valve

provides fine metering of fluids in one body

High-pressure, coaxial metering, flow-control valves can be used in missiles, sea service, ground-support equipment, machinery automation, chemical, petroleum, hydraulic, and pneumatic fields. Unit eliminates the use of a by-pass valve in conjunction with a discharge flow-control valve and extra plumbing, providing fine metering of air, gas, or liquid under low or high pressure in one body. Coarse or fine adjustments are easily made by fingertip control. Coaxial flow pattern

PRODUCT APPLICATION

HANSEN SYNCHRON TIMING MOTORS

synchronous power source for

ELAPSED TIME INDICATORS

Hansen SYNCHRON motors being assembled into Hobbs engine hour meters

JOHN W. HOBBS CORPORATION, a leading manufacturer of running time meters, uses Hansen SYNCHRON Timing Motors to provide the power for efficient, dependable, long-lasting operation of such devices. The elapsed time indicators measure running time on such typical installations as machine tools, air compressors, motor generator sets, and other equipment run by alternating current.

HANSEN SYNCHRON TIMING MOTORS exceeded the requirements set for the synchronous motor and integral gear train providing the accuracy of time so vital to the operation of Hobbs instruments — including accurate performance over a wide range of ambient temperatures to meet certain military requirements. Hansen SYNCHRON motors are furnished to Hobbs to meet voltage specifications that vary from 120 - 240 - 480 volts, at 25 - 50 and 60 cycles.

The application described demonstrates another way in which Hansen SYNCHRON motors serve as an integral part in product operation. You may be able to profit from such dependable performance applied to your timing application, now being planned or in production. SEND TODAY for informative folder detailing specifications and technical data on all Hansen SYNCHRON Timing Motors and Clock Movements.

HANSEN MANUFACTURING COMPANY, INC.
PRINCETON, INDIANA

HANSEN REPRESENTATIVES:

THE FROMM COMPANY
5150 W. Madison, Chicago, Illinois

H. C. JOHNSON AGENCIES, INC.
Rochester, N. Y. — Buffalo, N. Y. — Syracuse, N. Y.
Binghamton, N. Y. — Schenectady, N. Y.

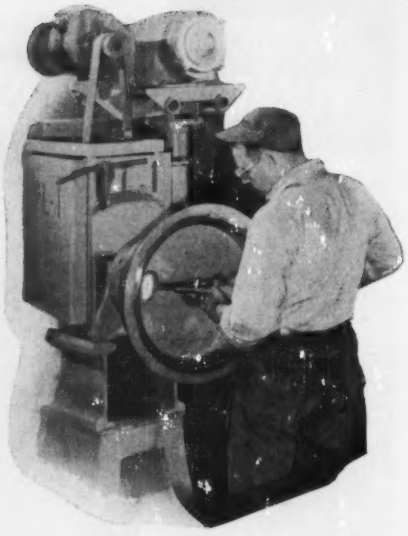
ELECTRIC MOTOR ENGINEERING, INC.
Los Angeles, Calif. — (Olive 1-3220)
Oakland, California

WINSLOW ELECTRIC CO.
New York, N Y. — Essex, Conn. (SOuth 7-8229)
Philadelphia, Penn. — Cleveland, Ohio

Sweet's Product Design File

Circle 477 on Page 19

What makes an A-P-C Craftsman?



Loyalty . . . pride of workmanship . . . skill—these are the qualities that make an A-P-C craftsman. A manufacturing specialist in stainless steel, the A-P-C craftsman has made the future of Alloy Products Corp. his future. Setting for himself highest product standards, he takes special pride and care in making every A-P-C product a product that fulfills your stainless steel needs best. These qualities combined with engineering know-how . . . complete, modern facilities—all under one roof—guarantee products with longer service life and lower maintenance costs. A-P-C stainless steel craftsmen keep your profits in mind on every job.

Just a postcard brings a quick reply to all your stainless steel requirement questions.

Craftsmen in Stainless Steel SINCE 1929

ALLOY PRODUCTS CORP.

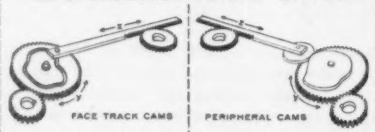
1067 PERKINS AVENUE • WAUKESHA, WISCONSIN

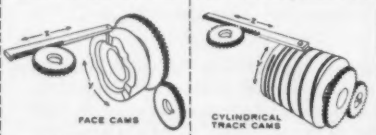
Circle 478 on Page 19

CAMS

✓ 2 & 3 DIMENSIONAL MASTER CAMS
✓ EXPERIMENTAL CAMS
✓ PRODUCTION CAMS

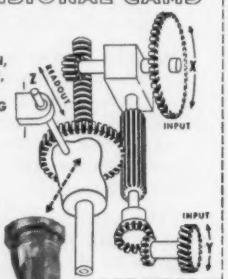
2 DIMENSIONAL CAMS





3 DIMENSIONAL CAMS

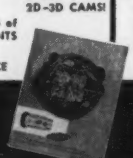
CONTROL CAMS FOR AUTOMATION, MISSILE GUIDANCE, NAVIGATION, JET FUEL METERING MACHINE TOOL CONTROL, ETC.

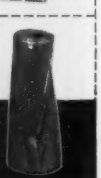


DESIGN & DEVELOPMENT OF SPECIAL CAM CONTOURS

- CAM PRODUCTION
- CAM INSPECTION
- PRECISION MACHINING of IRREGULAR CONTOURS
- PRECISION MACHINING of STANDARD COMPONENTS
- CAM DESIGN and CONSULTATION SERVICE

SEND FOR BROCHURE 2D-3D CAMS!





THE PARKER-HARTFORD CORPORATION CAM DIVISION
700 FRANKLIN AVENUE • HARTFORD, CONNECTICUT

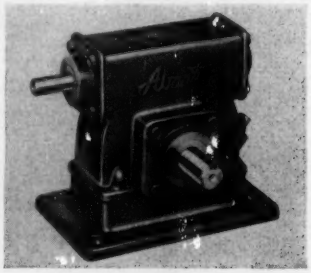
Circle 479 on Page 19

helps to pressure balance the forces between the hollow and solid valve stem. Sizes range from ¼ to 1¼ in. NPT; maximum operating pressure is 10,000 psig. **Kell-Strom Tool Co. Inc.**, 214 Church St., Wethersfield, Conn.

Circle 767 on Page 19

Speed Reducer

fractional-horsepower unit is fully enclosed



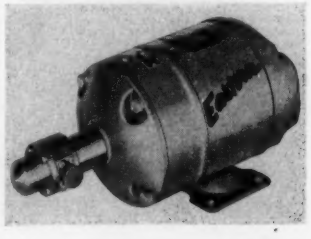
Type 2⅝A speed reducer provides ratios from 5 4/5:1 to 100:1, handling inputs of ¼ to 2 hp at 1800 rpm and 1/6 to 1½ hp at 1200 rpm. Right-angle drive, horizontal worm-gear unit is built for continuous duty in stokers, conveyors, agitators, spraying equipment, and other applications. Fully enclosed, it can be mounted in any position. Reversible units are available with input or output shafts projecting from either side of the housing, or from both sides. **Dept. MD-1, Abart Gear & Machine Co.**, 4834-36 W. 16th St., Chicago 50, Ill.

Circle 768 on Page 19

Positive-Displacement Pumps

in belt and coupling-drive types

Vane-type, positive-displacement pumps are designed to pump non-lubricating liquids at flows from 1 to 3 gpm and pressures to 60 psi. Self-priming units, Model VW-5 and VW10, have a cam-shaped



Are your "dead storage" files more efficient than your active drafting files?

No doubt about it—it's important to keep correspondence carefully filed; *but* it is even more important to equip your drafting department with modern filing facilities that keep active and semi-active drawings readily accessible, fully protected—and in a minimum of space.

Your draftsmen, your productivity, deserve new Hamilton space-and-time-saving equipment—from Bruning

Inadequate or antiquated equipment in your drafting room *can cost you more money* than you imagine in lost time, errors, done-over work, and low morale. Hamilton equipment is *engineered* to fit your needs. It is *designed* to improve the practical, day-to-day creativity of your engineers or draftsmen. Its performance has been tested and *proved* in many thousands of installations. Our designers will gladly assist in the planning of your department. No obligation, of course.

HAMILTON UNIT SYSTEM FILES The Hamilton system offers maximum protection and capacity in minimum floor space. Each drawer of the patented shallow drawer units is equipped with a tracing lifting mechanism. Every tracing becomes a top sheet, instantly accessible. Unit sections can be assembled in a number of arrangements, stacked safely to any practical height. They stand up to hard usage, perform perfectly year after year.

Hamilton L-Contour Table
Prestige-assured, individualized work area providing complete board adjustment plus extra storage and reference area.

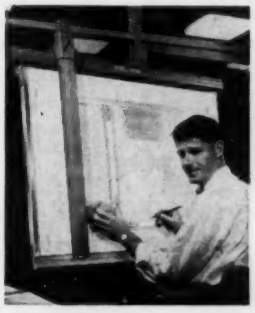
Hamilton CL 100 Drafting Table
Conserves dollars, yet rugged canted-leg design provides modern styling and convenience with long-term durability.

Hamilton Auto-Shift Table
Built-in mechanism adjusts board to individual height and slope requirements, provides full accessibility, reduces errors.

Put draftsmen in a "position" to do better, faster work!

Bruning's all-new Neoglide drafters literally help draftsmen straighten up and do faster, better work.* They provide complete maneuverability on any board at any angle without adjustment! Reinforced U-beam construction assures rigidity, strength, and accuracy. Resistance-free movement of vertical beam and hidden counterweight provide fast "floating" action. Touch-control protractor head gives automatic, pinpoint angle selection.

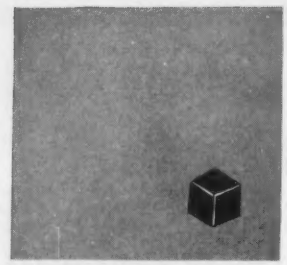
*Study of 300 draftsmen showed 35% savings in drawing time—1/5 the backaches—on vertical or near vertical boards.



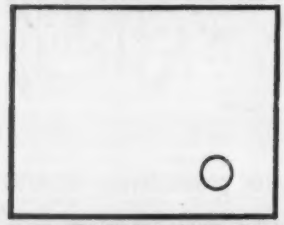
BRUNING

CHARLES BRUNING CO., INC.
1800 CENTRAL RD., MT. PROSPECT, ILLINOIS

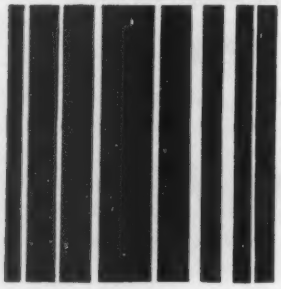
Circle 480 on Page 19



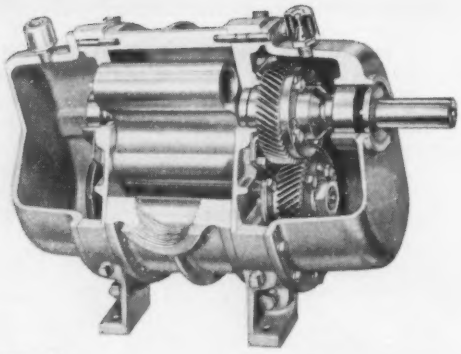
SMALLEST CUBE DIMENSIONS

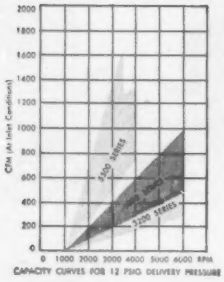


LIGHTEST WEIGHT



WIDEST PRESSURE RANGE





WITH M-D 3-LOBE BLOWERS

If space and weight of the blower is a concern in your design problem, consider this fact. M-D rotary positive blowers because of their unique 3-lobe design require smaller cubic space than any other blowers. A survey shows that a 14 PSI M-D takes 3/4 to less than 1/10 the space of competitive models . . . and in some cases are only 1/10 the weight.

M-D Blowers operate at wider pressure and speed ranges than any other rotary positive blower. Capacities of 30 production models range from 30 to 4000 CFM, pressures to 15 PSIG single, 70 PSIG multi-stage.

md

For full information write

M-D BLOWERS, INC., RACINE, WISCONSIN

A SUBSIDIARY OF MIEHLE-GOSS-DEXTER, INC.

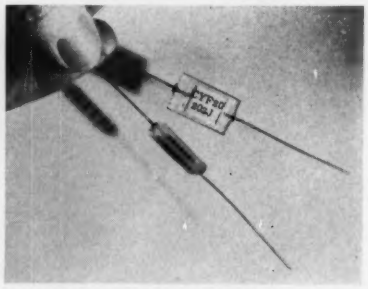
pumping chamber which delivers pulsation-free liquid flow. Vanes are held in positive contact with the pumping chamber at all times, and positioning of vanes is independent of hydraulic pressure or centrifugal force. Pumps are available in belt and coupling drive. **Eastern Industries Inc.,** 100 Skiff St., Hamden 14, Conn.

Circle 769 on Page 19

Glass Capacitor

has range of 560 to 5100 mmf

CYF-20, new capacitor in a series of fusion-sealed, moisture-resistant glass units, is for use in high-reliability systems. Capacitance range is 560 to 5100 mmf, more than quadrupling the range of earlier



units in the series. Capacitors in the series exceed MIL-STD-202A moisture requirements by a factor of four and meet or exceed performance requirements of MIL-C-11272B. Temperature coefficient of capacitance is 140 ±25 ppm per deg C over operating range of −55 to +125 C. CYF-20 has a dc working voltage of 500 at capacitances between 560 and 3600 mmf and of 300 between 3600 and 5100 mmf. **Corning Glass Works,** Corning, N. Y.

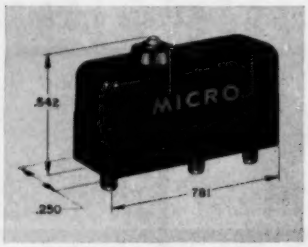
Circle 770 on Page 19

Subminiature Switch

for temperature or pressure control

Sensitive subminiature switch maintains a differential travel within 0.001-in. Despite the close tolerances, neither electrical nor mechanical performance has been sacrificed. Switch is designed for temperature or pressure control for military, electronic or instrument applications.

Circle 481 on Page 19



Operating force for the switch is 3½ oz maximum; release force, 1 oz maximum; differential travel 0.001-in. maximum; overtravel 0.003-in. minimum, and 0.008-in. minimum break travel. **Micro-Switch Div., Minneapolis-Honeywell Regulator Co.,** 800 Second Ave., New York 17, N. Y.

Circle 771 on Page 19

Phenolic Laminates

for use where flame retardancy is required

Two XXXP phenolic laminates are designated Panelyte 833 (unclad) and 8334 (copper-foil surface). They are suited as insulating bases for many printed-circuit applications previously requiring the use of more expensive epoxy-paper laminates. For general use, they are suitable where flame retardancy is required in addition to high quality XXXP properties. Use of the laminates as a substitute for epoxy resin is possible because of their excellent dielectric properties, ease of processing, and flame retardancy. Grade 833 is self-extinguishing by ASTM D 635. One ounce copper-foil-clad 8334 has 8 lb per in. peel strength and withstands blistering for 8 sec at 500 F solder temperature. **Dept. WMG, Panelyte Div., St. Regis Paper Co.,** Trenton 8, N. J.

Circle 772 on Page 19

Tubing Valve

has large port openings and minimum pressure drop

Compactness, light weight, and ease of installation are outstanding features of SpaceSaver stainless-steel tubing valve. Capable of handling liquids and gases at 12,000 psi, valve is priced for practical use at much lower pressures. Large port openings, with minimum pressure

AMPCO®

Do you have to

COPE WITH THESE CONDITIONS?

**High heat as compared to other copper-base alloys.*

you combat them all with an

AMPCO® metal

What does a copper-base alloy have to do for you? Whatever it is, there's a grade of Ampco metal — or other Ampco alloy — that does the job exactly.

Equally important, you can select the best, most economical form of production — sand casting, centrifugal casting, shell mold, precision casting, forging, fabrication, extrusion, sheet, plate.

Call in your Ampco field engineer. Write for bulletin.

G-206

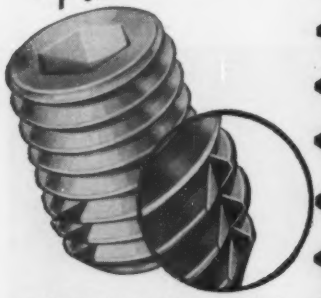
AMPCO METAL, INC., Dept. 30C, Milwaukee 46, Wis.

WEST COAST DIV.: HUNTINGTON PARK, CALIFORNIA • SOUTHWEST DIV.: GARLAND (DALLAS COUNTY), TEXAS

Circle 482 on Page 19

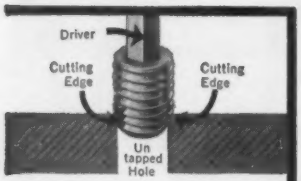
NEW SELF-TAPPING* SET SCREW

actually "Pulls Itself In"



- Eliminates tapping problem!
- Increases product reliability!
- Cuts production cost!

You can completely eliminate the tapping problem while increasing product reliability with Setko *Self-Tapping Set Screws!* Exclusive, tool-sharp, cutting edges, located on the lower threads of the screw, actually cause the screw to "pull itself in"—Shavings are gathered into the oversize slots ...Holds securely even under extremes of vibration. You'll find they serve equally well to clean out painted holes or as reaming screws. Can be reapplied many times without loss of cutting or holding ability.



Note how three-grooved cutting edges give full cutting tooth for easy "pulls itself in" application. Gives tight, snug fit, in plastic or metal.

SEND FOR FREE TEST SAMPLES TODAY...

Tell us your requirements and we'll forward full information and recommendations, along with your samples, free of charge.

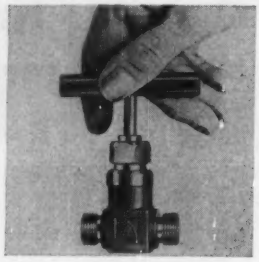
*Patent pending

SETKO Set Screw & Mfg. Co.

824 28 Main Street, Bartlett, Illinois

We specialize in solving puzzling screw problems!

Circle 483 on Page 19



drop through the valve, are a major advantage. Three sizes are available for 1/8, 1/4, or 3/8-in. OD tubing. **Autoclave Engineers Inc.**, 2945 W. 22nd St., Erie, Pa.

Circle 773 on Page 19

Adjustable-Speed Drive

for operations requiring 1/4 to 1 hp

Redesigned Type 5 VA Varidrive offers speed ratios to 10:1, from 4 to 10,000 rpm. It is available in 1/4, 1/3, 1/2, 3/4, and 1 hp, triple and single phase, 60 cycle. New hand-control assembly, operated by a fluted knob, turns with one-seventh the effort of previous controls. Speed drift is prevented by a positive anticreep device. Light weight and compact size make drive suitable for direct mounting on or inside driven machine. Unit performs the work of a motor, speed changer, cone pulley, or controller and gear box. Drive Type 5 VA

can be mounted in a variety of positions. **U. S. Electrical Motors Inc.**, P. O. Box 2058 Terminal Annex, Los Angeles 54, Calif.

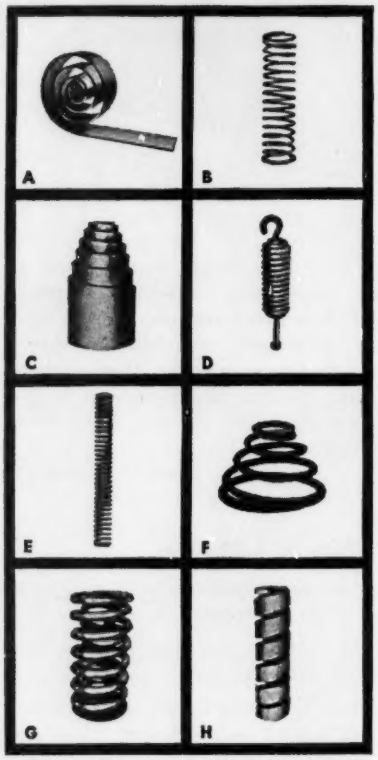
Circle 774 on Page 19

Tube-Reducing Adapter

has separate O-ring seal and collet grip

Tube-reducing adapter shortens substantially the over-all length required with typical standard reduc-

Can you identify these springs?



A. flat B. helical C. volute D. extension E. helical F. cone G. helical, triple-coil H. rectangular section

Over One Million ALCO SPRING DESIGNS

ALCO's complete line of "performance-rated" springs ranges from small springs for light work to heavy-duty triple-coil springs for heavy, sustained work.

In over 80 years, ALCO engineers have produced more than one million spring designs to serve almost every conceivable application.

For your next spring job, contact your nearest ALCO sales office. To obtain brochure, ALCO *Springs for Industry*, write to ALCO Products, Inc., Dept. 160, Schenectady, N. Y.

ALCO

ALCO PRODUCTS, INC.
NEW YORK
SALES OFFICES IN PRINCIPAL CITIES

Circle 484 on Page 19

SILICOLOGY *Studies in Silicones*

HOW THESE TIME-TESTED MATERIALS CAN WORK FOR YOU

Silicones Go Into High Gear... To Back Up the New Car Warranty

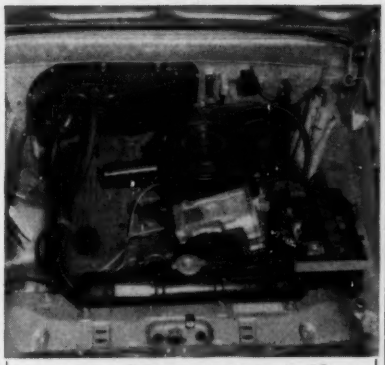
Automobile designers sharpened their pencils for the 1961 models. The new "12-months-or-12,000-miles" warranty calls for much more than a new piece of paper. Needed is the kind of extra assurance that products such as silicones provide to back up performance.

With this new look at quality control, UNION CARBIDE Silicones are becoming more popular with designers, production engineers, dealers, and most important, with customers. Yet these high-performance products usually cost only a few cents more than most of their out-dated counterparts.

SILICONE RUBBER SETS NEW STANDARDS

Silicone Rubber, in various compounds, performs better than organic rubber in many areas. Among other things, it stands up under extremes of heat and cold, yet permits precision molding at favorable fabricating rates.

Silicone rubber sparkplug boots remain unaffected by water, heat—even ozone—for a maximum service life. Other compounds work just as well as dielectric coating on battery terminals and distributor caps. And a special electrically conductive silicone rubber is used as ignition wire core on many models, reducing car radio interference below annoying levels. In transmissions and differentials, silicone rubber seals and gaskets stay on the job in spite of attack from oil, hydraulic fluids, anti-freeze—under conditions of elevated temperature.



CLOSE-UP of compact engine in Chrysler Motor's new 1961 Valiant series.

LOOK WHAT SILICONE FLUIDS CAN DO

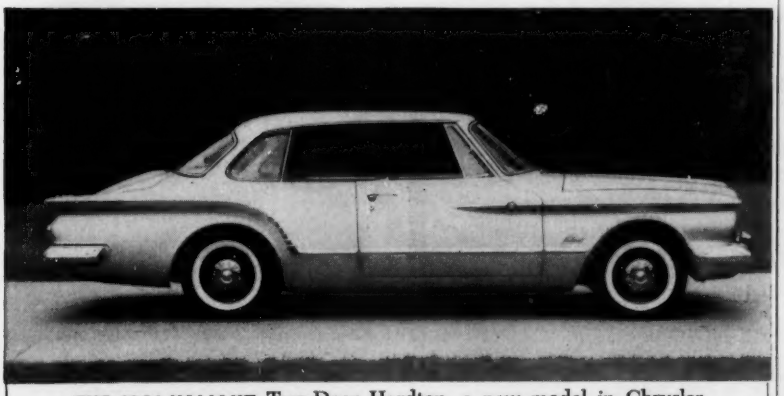
There are an amazing number of places where silicone fluids work to reduce production costs and to boost the performance of the finished car. We can mention only a few.

To begin, silicone anti-foams in coolants and cutting oils keep costly, efficiency-robbing foaming of these agents to a minimum. In the production of tires, rubber floor mats, molded rubber accessories and radiator hoses, there are silicone release agents which help the finished product slip easily and quickly from intricate molds without loss of detail.

In the car itself, silicone damping fluids frequently keep delicate instruments from bouncing around, even when road conditions are extremely rough. In certain cars, variable-speed drive systems for the cooling fans use silicone fluids for powering because these remain stable over wide ranges of temperature. Among other things, silicone fluids are excellent leveling agents for acrylic lacquers... all-weather lubricants for car weatherstripping... and excellent constant-viscosity lubricants in special applications.

MORE TO COME FROM RESEARCH

There are hundreds of other ways in which silicones are serving the automotive industry. Every day, new uses are coming from research, more are being developed in the laboratory. Perhaps there is a place where your own operation can use them profitably, to improve product performance and production efficiency. We suggest you send the coupon below for further information related to your specific needs.



THE 1961 VALIANT Two-Door Hardtop, a new model in Chrysler Motor's Compact Car V-200 series, uses Silicone Products in many areas to improve the reliability, durability, and reduce production costs.

UNION CARBIDE

SILICONES

UNION CARBIDE is a registered trade mark of Union Carbide Corporation.

Silicones Division
Union Carbide Corporation
Dept. CL-0102
270 Park Avenue, New York 17, N. Y.

In Canada: **Union Carbide Canada Ltd., Bakelite Division, Toronto 12.**

Please send me data on _____

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NAME _____

TITLE _____

COMPANY _____

ADDRESS _____

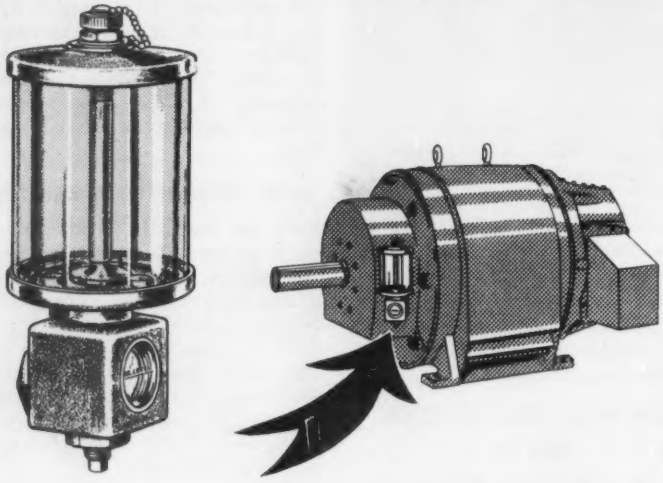
CITY _____ ZONE _____ STATE _____

Circle 485 on Page 19

New Ideas From Oil-Rite

. . . to solve your lubrication problems

Are you looking for low cost Oilers — automatic lubricating systems — special lubricators, systems or components — *ways to reduce costs?* You will find the answer in the Oil-Rite line — complete with engineering service.



HERE'S A SAMPLE

A manufacturer of large electric motors wanted visual proof of proper oil level within a device which continuously replenishes oil as used by bearings. Oil-Rite suggested this lubricator with a large sight in base for easy visual check of oil level. It also includes a top filler cap — an exclusive Oil-Rite feature on all constant level lubricators.

Consult us on your requirements for lubricating equipment. Specific information will be furnished promptly to help you select suitable equipment, adapted for your individual application. Benefit from our *25 years of accumulated knowledge and skill* in this field. There is no obligation.

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Oiling Systems • Valves
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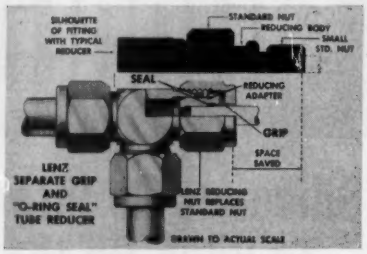
Circle 486 on Page 19



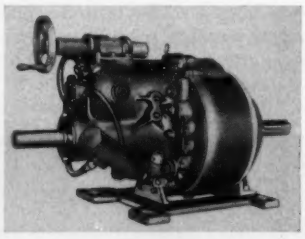
ers, as shown. Unit utilizes a separate, nondamaging collet grip and O-ring seal. Reducer bushing is internal, making possible the reduction in over-all length. Method also eliminates one nut and sleeve in the reduction. It is designed to cut down on heavy inventory requirements of special fittings. From stock, 42 sizes available range from 2 x 1½ in. to ⅜ x ¼ in. standard. **Lenz Co.**, 3301 Klepinger Rd., Dayton 1, Ohio.

Circle 775 on Page 19

Adjustable-Speed Transmission

for high-torque, heavy-duty applications

New 10-hp adjustable-speed hydraulic transmission is a continuous-duty unit which provides infinitely adjustable speeds from zero to 1600 rpm for high-torque, heavy-duty applications. Unit drives at 1800 rpm or less with any 2 to 10-hp motor or 20-hp gas engine. Precise speed selection is obtained by rota-



tion of hand wheel. **Roberts Electric Co.**, 849 W. Grand Ave., Chicago 22, Ill.

Circle 776 on Page 19

Digital Shaft Encoder

has high accuracy

Miniature Verisyn digital shaft encoder VS-256E is designed for high-accuracy, limited-space and power applications, and low torque, such as in guidance and navigation sys-

tems. In a 1½-in. diam by 2-in. length size, including electronics, unit gives resolutions as required of one part in 2^{14}, 2^{15}, and 2^{16} in a single turn. Other configurations and accuracies to 2^{21} are available. Output is in the form of alternate fine and coarse pulse trains on separate lines, such as to provide a complete angular position answer, with respect to a reference radius, into a 14 to 16-stage binary counter every 40 millisec. Accuracy is maintained up to slew rates of 1

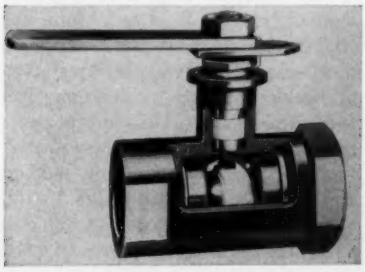
to 4 min per sec without a time correction. **Data Tech**, 238 Main St., Cambridge, Mass.

Circle 777 on Page 19

Ball Valves

in sizes from ¼ to 2½ in. for pressure to 400 psi

Line of ball valves features adjustable-stem seal, self-adjusting ball which seals with flow in either direction, and stem shoulder to prevent ball from being forced downward. Included are valves with Navy-G bronze or semisteel cast bodies, or with brass, steel, and 303 or 316 stainless-steel bar-stock bodies. Both cast and bar-stock types have full-round, pipe-sized passage or restricted passage as desired. Available now with flexible self-forming Teflon seats and seals, valves will soon be furnished in rubber, polyethylene, or Kel-F. Sizes range from ¼ to 2½ in. for



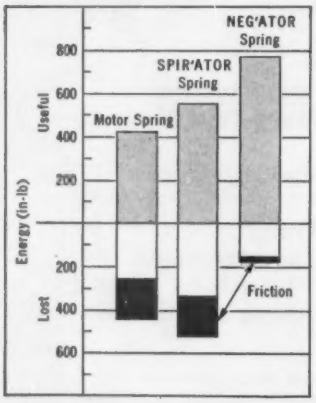
14 WAYS TO
CUT DOWN-TIME!
fabric reinforced
VEE-DAM PACKINGS*
14 standard styles . . .
plus custom compounds
when necessary
• Suitable for use with a wide variety of liquids and gases on heavy-duty industrial equipment
• Positive control of annular leakage at the joint
• Eliminate need for solid rings
• Effective sealing over a wide temperature range
• Pressure is never a problem with a Linear Vee-Dam
* The Vee-Dam design is patented
SEND FOR special bulletin with detailed technical data on VEE-DAM PACKINGS. Linear, Inc., State Road and Levick St., Philadelphia 35, Pa.
"PERFECTION IN RUBBER"
LINEAR
LINEAR, Inc., STATE ROAD & LEVICK ST., PHILA. 35, PA.

Circle 487 on Page 19

Drive it with

HUNTER SPRING POWER

Energy comparison of three Hunter motor springs having same weight of material



For a detailed comparison of these three drive units, write for a copy of "Motor Springs" to the address below.

HUNTER POWER SPRINGS

These familiar springs are better than ever before. Using materials and techniques discovered in manufacturing constant-force springs, Hunter has bettered the performance of, and added life to, conventional power springs.

HUNTER SPIR'ATOR® MOTORS

These prestressed spiral springs by Hunter are related to the power spring and the NEG'ATOR spring. They *look* like power springs—are *made* like NEG'ATOR springs. SPIR'ATOR motors produce as much as twice the length of running cycle in the same size package as a power spring.

HUNTER NEG'ATOR® MOTORS

These unusually long-running motors release the maximum useful energy and provide constant torque output. In NEG'ATOR motors, design engineers have a unique mechanical drive unit that provides many more turns than any other, is compact, very powerful and will not jump or skip.

HUNTER

HUNTER SPRING COMPANY

A Division of American Machine and Metals, Inc.

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SPRINGS • STAMPINGS • QUALITY CONTROL EQUIPMENT

DIVISIONS OF AMERICAN MACHINE AND METALS, INC.: Troy Laundry Machinery Riehle Testing Machines • De Bothezat Fans • Tolhurst Centrifugals • Filtration Engineers • Filtration Fabrics Niagara Filters • United States Gauge • Rahm Instruments • Lamb Electric Co. • Hunter Spring Co. • Glaser-Steers Corp.

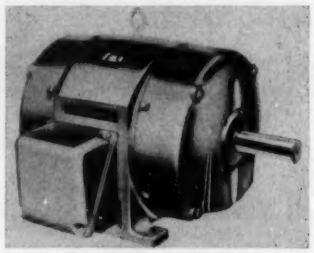
pressures to 400 psi water-oil-gas, and temperatures to 450 F. **Homestead Valve Mfg. Co.**, Coraopolis, Pa.

Circle 778 on Page 19

Multispeed Motors

in two, three, and four-speed units

Multispeed motors drive machines requiring more than one constant speed. Available in two, three, and four-speed units, they have a variety of torque and horsepower characteristics. Variable-torque motors are suited for such applications as fans, blowers, and centrifugal pumps. Constant-torque motors are suited for applications where friction is the chief component of the load, such as conveyors, elevators, stokers, and



printing presses. Constant-horsepower units are suited for driving lathes, boring mills, other machine tools, and winches. Motors are available from 1 to 100 hp, two or three-phase, ac, in open, enclosed, or explosionproof types. Speeds range from 3600 to 450 rmp. **Howell Electric Motors Co.**, 16316 W. Seven Mile Rd., Detroit 35, Mich.

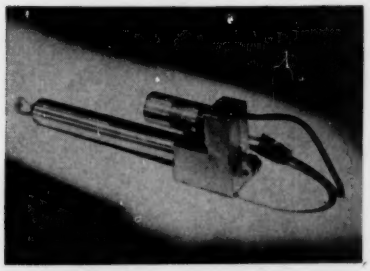
Circle 779 on Page 19

Linear Actuator

provides 500 lb over 6-in. stroke

Linear actuator uses a dc motor to operate a precision ball screw. It provides 500 lb over a 6-in. stroke. Rate of travel is fixed at 10 ipm, but can be adjusted at the factory to meet other requirements. Maximum allowable tension or compression load is 2500 lb. Unit meets specs for environment, radio noise shielding. Temperature range is −65 to 300 F. Unit operates on 27 to 100 vdc; universal ac/dc operation is also available. Actuator measures 14-7/16

Circle 488 on Page 19



in. long by 1¾ in. wide, by 3¾ in. high. Weight is 3 lb, 14 oz. **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, Ohio.

Circle 780 on Page 19

Vacuum Filter

handles flows to 4000 cfm

Model 1125MV filter for vacuum service incorporates a large, impregnated felt cartridge that is reuseable. Filter removes particles as small as 5 microns without restricting vacuum flow, and also removes oil fumes. Filter handles flow to 4000 cfm, and is equipped with a petcock for draining large sumps. It is available from stock in pipe threads of ¼ to 2 in., and with pipe flanges for lines to 8 in. **Wilkerson Corp.**, 1646 W. Mansfield, Englewood, Colo.

Circle 781 on Page 19

High-Strength Steels

are available as plates, hot-rolled sheets and strip

Two columbium-bearing, high-strength, low-alloy steels, High Strength No. 6 and No. 7, offer minimum yield points of 50,000 and 45,000 psi respectively. Grades are available as plates, hot-rolled sheets, and hot-rolled strip. Corrosion resistance is equivalent to mild, non-copper-bearing steels. Formability characteristics permit simple bending across the rolling direction, flanging, and light forming operations of the type regularly performed on standard commercial-quality sheet and plate. High Strength No. 6 exhibits welding properties similar to a 0.20-per cent carbon steel; No. 7 has properties similar to a 0.10-per cent carbon steel. **Armco Steel Corp.**, Middletown, Ohio.

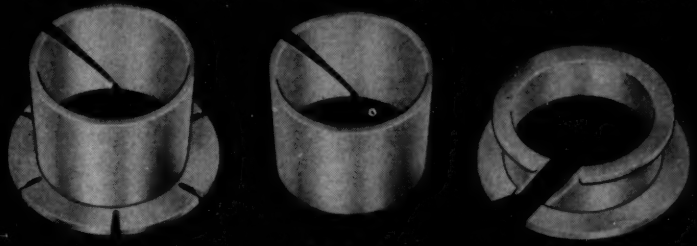
Circle 782 on Page 19

Circle 489 on Page 19→

LONG LIFE, *THOMSON* "Snap-In"

NYLINERS®

–*BEARINGS of smooth, tough DuPont* NYLON



Low Cost FLANGED Nyliner | Low Cost SLEEVE Nyliner | Low Cost DOUBLE-FLANGE Nyliner

COST LESS to BUY
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Additional Benefits:

- CLOSE FIT
- LONGER LIFE
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- RESIST CORROSION
- LOW FRICTION
- RESIST POUNDOUT
- NO FRICTION OXIDATION
- DAMP VIBRATION
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- NON-CONTAMINATING
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- SILENT OPERATION
- LIGHTEST WEIGHT
- REDUCED WEAR

Engineered to Solve Problems . . . Improve Products . . . Reduce Costs!

NYLINER Bearings are a highly engineered thin liner of DuPont Nylon, designed to bring bearing users the many benefits of Nylon as a bearing material by solving most of the limitations surrounding its use. The compensation gap principle assures maintenance of diametral tolerances for precision applications.

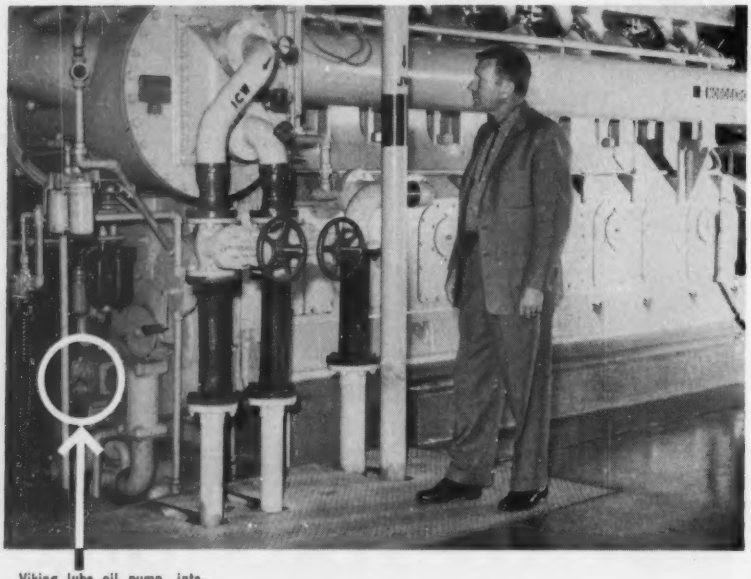
Seven Standard Types available from stock. Write for literature and name of your local representative who stocks NYLINER Bearings for immediate shipment.

THOMSON INDUSTRIES, Inc.

DEPT. 4, MANHASSET, NEW YORK

Also— —Manufacturers of BALL BUSHINGS . . . the Ball Bearing for Linear Motions and 60 CASE . . . Hardened & Ground Steel Shafting

EVEN MISSILE BASE POWER UNITS USE VIKING PUMPS



Viking lube oil pump, integrally mounted on Nordberg diesel engine, has square flanged ports and valve on head.

Wherever smooth, dependable pumping is required, you're apt to find Vikings. No wonder, then, that Viking Pumps were used on the Nordberg diesel generating units at Vandenberg Air Force Missile Base in California. The base must always be ready to launch its Atlas guided missiles without fail and the generating plant insures an independent, dependable source of power for this purpose. Lubrication of each of the six Nordberg engines in the 8000 horsepower, 5700 kw plant is supplied through Viking Pumps.

For the most dependable pumping equipment available, specify Viking Pumps. Used integrally or as independent units, Viking pumps can be depended upon for efficient service and long life.

For information, write for catalog 61SH

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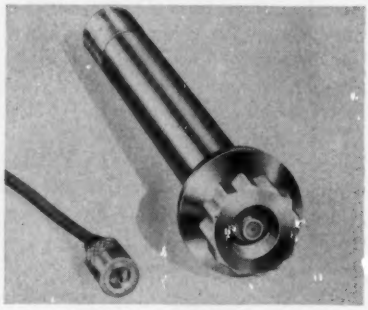
Cedar Falls, Iowa, U.S.A. • In Canada, It's "Roto-King" Pumps
See Our Catalog in Sweet's
Product Design File

ENGINEERING DEPARTMENT
EQUIPMENT

External-Wrenching Bolt

incorporates built-in strain gage

Standard Strainsert bolt consists of an electric strain gage installed in neutral axis of bolt shank, with a screw-type connector embedded in bolt head. There is no reduction in allowable load or protrusion beyond configuration of ungaged bolt. Available in all external-wrenching standard cap-screw, hex-head, and 12-point super-strength bolt sizes, bolt indicates bolt-tension load with



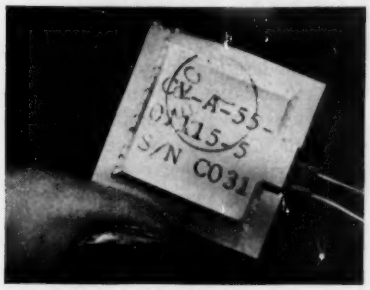
better than 1 per cent accuracy. Tightening loads or changes in bolt load due to vibration, shock, and wear can be observed or recorded remotely. Special fasteners are gaged to specifications for testing, control, safety, load force, and acceleration - measuring purposes. **Strainsert Co., Div., Polyphase Instrument Co.**, E. Fourth Street, Bridgeport, Pa.

Circle 783 on Page 19

Temperature Transducer

for temperatures from −320 to +280 F

Model Y-0218 transducer measures skin temperatures and level of liquid nitrogen, as well as acting as the temperature-compensation element for constant-signal readout. It is for use in temperatures from −320 to +280 F. Time constant for 63.2 per cent of tempera-



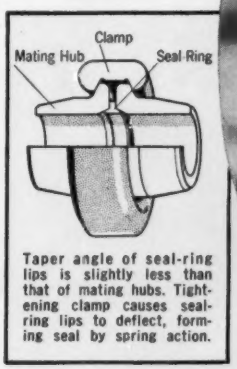
ture span is better than 700 millisec, and time response at 99 per cent for a step temperature is less than 5 sec. Circuitry is simple since unit functions as one arm of a four-arm bridge. Excitation is in the order of 2 ma. Instrument withstands 100 g at 100 to 700 cps. Stainless-steel case permits welding the instrument to its relative component. Transducer is approximately 1 in. square, is less than 0.040 in. thick, and weighs less than 1 gram. **Crescent Engineering & Research Co.**, 5440 N. Peck Rd., El Monte, Calif.

Circle 784 on Page 19

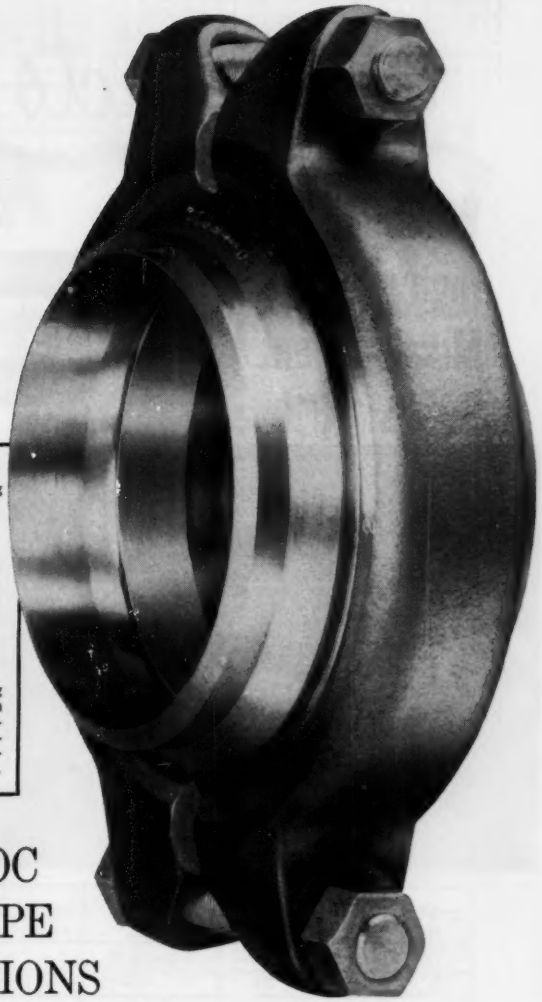
Potentiometer

adapts strain gage as rebalancing element

ElectroniK 17 industrial process potentiometer incorporates an electromechanical strain gage, designated Stranducer, as the rebalancing element, providing infinite resolution. Potentiometer can be mounted in a standard 19-in. relay rack, on a panel or bench, or can be made portable. First units are a single-pen strip recorder, circular-chart recorders, and a circular-scale indicator. Unit has two amplifiers, one solid state and the other with vacuum tubes and transistors. Front or display module can be removed easily and replaced with a strip or



Taper angle of seal-ring lips is slightly less than that of mating hubs. Tightening clamp causes seal-ring lips to deflect, forming seal by spring action.



GRAYLOC PIPE CONNECTIONS HOLD PRESSURE WITHOUT LEAKING

From a full vacuum to extreme internal pressure, GRAYLOC pipe connections will not leak—will not blow out.

It's an all steel assembly with a pressure aided seal that can be quickly and easily disconnected. The seal ring is even re-usable! Yet, for all its sealing power, it's lightweight and small in size.

GRAYLOC pipe connections are manufactured in standard stock sizes from 1″ to 30″, but special sizes can be manufactured on request. They are also available made of corrosion resistant metals.

Learn how GRAYLOC pipe connections can save you time, space and money. Write for the all new GRAYLOC catalog.

GRAYLOC SALES DIVISION

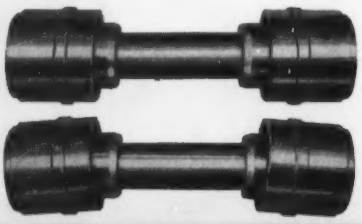
GRAY Tool Company

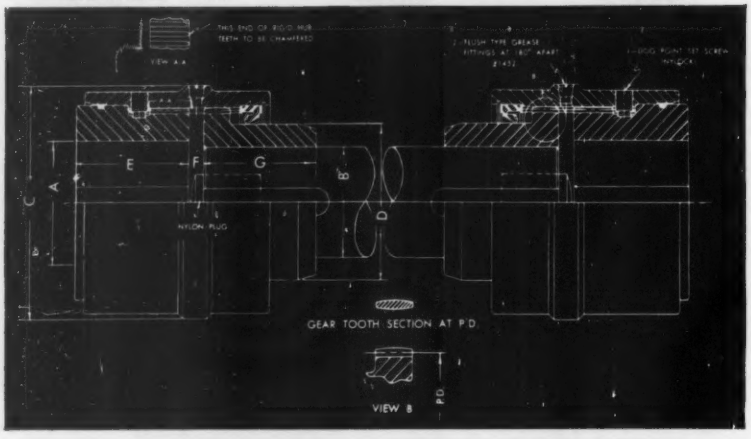
6006 P. O. BOX 2291 HOUSTON 1, TEXAS Riverside 7-1240

Circle 491 on Page 19

design facts....on

WALDRON High Misalignment Series "X"





COUPLING SIZE	H.P. PER 100 R.P.M.	MAX. BORE RIGID HUB A	MAX. BORE GEAR HUB B	C	D	E	F	G
1¼X	3½	1⅜	1¼	3¾	2	2⅛	¼	2
2X	12	2⅛	2	4 17/32	2⅞	2⅜	5/16	2¼
2½X	26	2¾	2½	5 5/16	3⅝	2¾	⅜	2¾
3X	50	3⅜	3	6 11/32	4¼	3¼	7/16	3¼
3½X	86	4	3½	7⅜	5	3¾	7/16	3¾
4X	130	4½	4	8 7/32	5¾	4¼	½	4¼
4½X	210	5¼	4½	9 7/16	6½	4¾	½	4¾

The Series X coupling is specifically designed for transmission of power in applications where shaft misalignment is too great to be handled by a standard gear coupling.

Each coupling assembly has two rigid hubs, mounted on drive shaft and driven shaft, each connected to a one piece sleeve by a spline used for driving purposes only. This spline extends only a portion of the hub length, and the remaining length of the hub is a turned surface which fits snugly into the counterbore in the sleeve to provide a suitable bearing surface. These two sleeves are connected by a floating shaft on both ends of which are mounted flexible hubs with gear teeth of unique design which permits misalignment up to 5°.

Series X couplings are easy to dismantle and reassemble. By backing off the set screws, the sleeves can be disengaged from the rigid and flexible hubs. Specially designed seals and steel protecting rings are held in place in the sleeves with Spirolox rings. End portions of the gear hubs are tapered for easy reentry of the seal in reassembly.

All load carrying parts are machined from high strength alloy steel. Floating shafts to customer specifications have nylon plugs inserted in each end to limit axial float and to prevent damage to the lathe centers of the roll shafts.

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MIDLAND-ROSS CORPORATION
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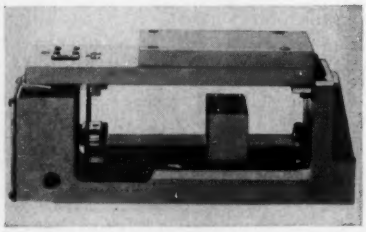
circular-chart recorder, or circular-scale indicator. Drive module, common and identical on all models, is also electrically and mechanically interchangeable. Calibrated accuracy is 0.25 per cent. Strip-chart instruments have pen speeds of 1, 5, and 15 sec, and those for circular-chart instruments are 5 and 15 sec. **Brown Instruments Div., Minneapolis-Honeywell Regulator Co.,** Wayne & Windrim Avenues, Philadelphia 44, Pa.

Circle 785 on Page 19

Force Transducer

has flexure pivots and cantilever main spring



New force transducer, a fast-response primary element, automatically senses and measures varying amplitude forces such as tension, pressure, weight, and thrust, for control purposes. Mechanical-to-electrical transducer incorporates cross-spring (flexure) pivots combined with a flat cantilever main spring. Flexure pivots prevent movement of load platform in crosswise or lengthwise planes, but allow flexure or bending in a third plane. Heavy, flat cantilever spring and flexure pivots permit direct mounting of load on the transducer. Standard models handle loads over an 8-oz to 1500-lb range. Overloading will not damage the unit or cause a shift in calibration. **Hydro-Pneu-Tronics Inc.,** 3666 E. 116th St., Cleveland 5, Ohio.

Circle 786 on Page 19

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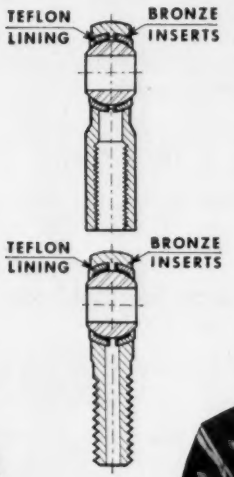

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13 ELECTRIC MOTOR SELECTOR by MACHINE DESIGN's Staff, July 24, 1958 (10 pages)

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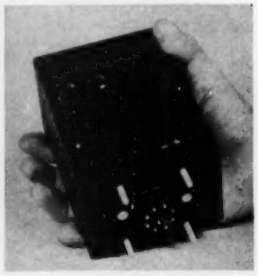

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THE ENGINEER'S

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Recent Books

Elementary Structural Analysis. *By Charles Head Norris, professor of structural engineering, and John Benson Wilbur, professor of civil engineering, Massachusetts Institute of Technology; 651 pages, 6¼ by 9¼ in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$10.50 per copy postpaid.*

Methods of stress analysis of a wide range of engineering structures are presented. This revised edition includes recent developments in advanced structural mechanics, matrix methods of analysis, use of electronic computers, model methods of stress analysis, and use of modern forms and materials. Application of moment distribution in the analysis of statically indeterminate structures is fully discussed.

Carbon: Proceedings of the Fourth Conference. *778 pages, 7 by 10¼ in., clothbound; published by Pergamon Press Inc., 122 East 55 St., New York 22, N. Y.; available from* MACHINE DESIGN, *$22.50 per copy postpaid.*

This survey of current work in the study of carbon is divided into five parts: 1. Surface properties, adsorption, and reactivity. 2. Electronic properties. 3. Carburization, graphitization, and structure. 4. Mechanical and thermal properties. 5. Carbon technology, friction, and wear.

Some specific topics included in the 80 papers are tensile and creep behavior of graphites above 3000 F, evaluation of a tension test for brittle materials, interpretation of mechanical behavior of carbons, elementary processes of graphite wear, dislocations in graphite, and electrical properties of carbon surfaces.

Analog Computation. *By Albert S. Jackson; 652 pages, 6¼ by 9¼ in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York*

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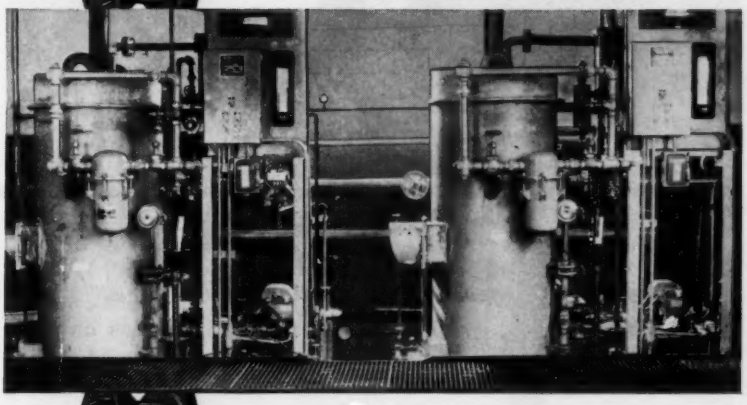

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Association Publications

Environmental Effects on Materials & Equipment. *Journal, 6¾ by 9¾ in., paperbound, stapled; published by Prevention of Deterioration Center, National Academy of Sciences-National Research Council, 2101 Constitution Ave., Washington 25, D. C.; available free to military offices and personnel, and to other qualified federal-government agencies; $25.00 per year to others.*

This new monthly abstracts journal is intended to aid design engineers, material scientists, and others charged with responsibility of guaranteeing reliability, operability, and durability of military and other materiel. About 40 substantive abstracts plus 40 or more extracts of current articles are scheduled for each issue.

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Engineering Professionalism in Industry. *104 pages, 6 by 9 in., paperbound; available from National Society of Professional Engineers, 2029 K St., Washington 6, D. C.; $4.00 per copy.*

A survey of engineers and engineering managers was conducted to determine how they define engineering professionalism and how they think it can best be advanced. Extensive "depth" interviews formed the basis of this study.

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building professionalism. 2. Meaning of engineering professionalism. 3. Present status in companies. 4. How professionalism can be advanced. 5. Other related issues.

A Checklist for the Organization, Operation, and Evaluation of a Company Library. *By Eva Lou Fisher; 64 pages, paperbound; published by Special Libraries Assoc., 31 East 10th St., New York 3, N. Y.; $2.00 per copy.*

Answers are provided to problems confronting management, research, technical, library, and administrative personnel who must decide whether to start a new library or to evaluate one already in operation. Discussion includes determining what types of materials are used and what services would be of particular use.

Government Publications

NASA Technical Notes. Copies of publications listed below are available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

TN D-439. Axial-Load Fatigue Tests on 17-7 PH Stainless Steel under Constant-Amplitude Loading. By Herbert A. Leybold, Langley Research Center; 17 pages, 7¾ by 10¼ in., paperbound, side-stapled; $0.50 per copy.

Tests were conducted at room temperature on notched and unnotched sheet specimens in condition TH 1050. For each specimen configuration *S-N* curves are presented along with predictions of fatigue behavior of notched specimens near fatigue limit.

TN D-506. Structural Behavior of Pressurized, Ring-Stiffened, Thin-Wall Cylinders Subjected to Axial Compression. By James P. Peterson and Marvin B. Dow, Langley Research Center; 24 pages, 7¾ by 10¼ in., paperbound, side-stapled; $0.75 per copy.

Axisymmetric mode of deformation of pressurized circular cylinders subjected to compressive end loads is examined and discussed with aid of available theory. Stresses and deformations obtained with the theory are compared with those obtained in tests of a 7075-T6 aluminum-alloy thin-wall cylinder with high internal pressure.

OTS Technical Reports. Copies of reports listed below are available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

PB 161706. Creep and Plastic Deformation in Cylindrical Shells. By Alfred M. Freudenthal and Maciej P. Bieniek, Columbia University; 16 pages, 8¼ by 10¾ in., paperbound, stapled; $0.75 per copy.

Problem of creep deformation and bending moments of a long cylindrical shell is solved under conditions of stationary creep. Results are checked by experiment.

Tests of steel cylinders under internal pressure producing large plastic deformation are presented. Relation between problems of nonlinear creep and plastic deformation is illustrated.

PB 161717. Investigation of the Compressive, Bearing, and Shear Creep-Rupture Properties of Aircraft Structural Metals and Joints at Elevated Temperatures. By Luke A. Yerkovich, Cornell Aeronautical Laboratory Inc.; 100 pages, 8¼ by 10¾ in., paperbound, stapled; $2.50 per copy.

High-temperature, short-time deformation properties of 16V-2.5Al titanium alloy and Vascojet 1000 alloy steel in tension, compression, bearing, and shear were investigated. Correlations of tensile creep-rupture properties with corresponding compression, bearing, and shear creep-rupture properties are presented.

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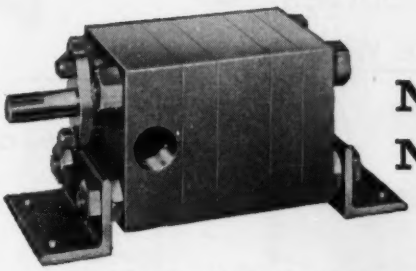

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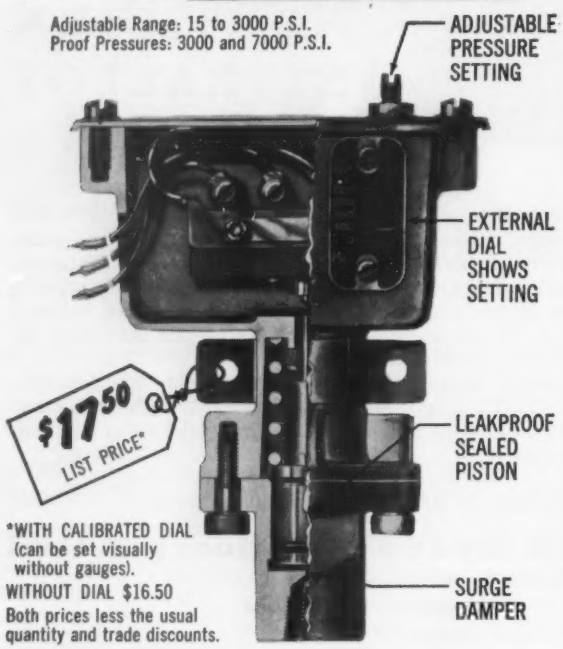

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Patents

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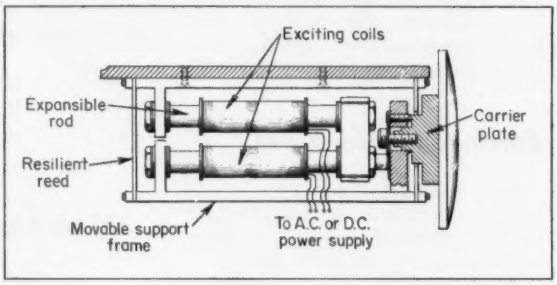
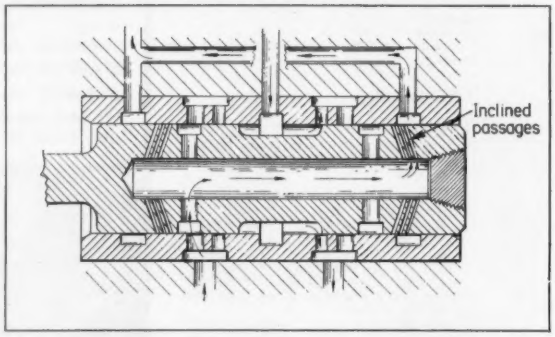


movable support frame and the carrier assembly shift to the left. Since ambient temperature changes affect both rods, their movements cancel each other, so that the position of the carrier assembly is unchanged. The time response for the assembly can be altered by changing the annular spacing between coils and rods. *Patent* 2,964,903 *assigned to General Electric Co. by William Asbury Porter and James Lester Good Jr.*

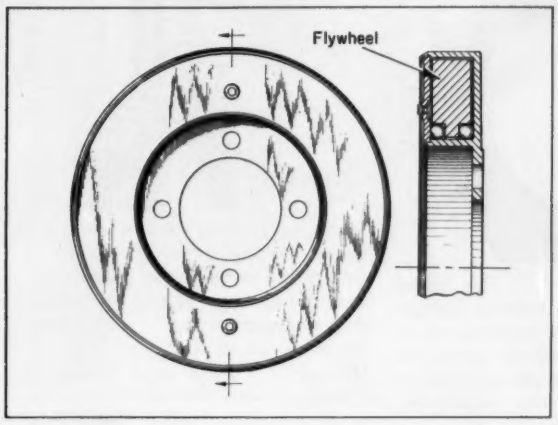
Flow-Compensating Control Valve



A single-stage flow-control spool valve uses inclined fluid passages to cancel out all hydraulic unbalance forces regardless of the position of the spool during operation. When unbalance forces are set up by fluid flow, the fluid acting on the inclined return passages produces a force component which, with the passages at about 69 deg, is almost exactly equal to the force tending to center the valve spool. This arrangement eliminates the need for a two-stage valve, since only

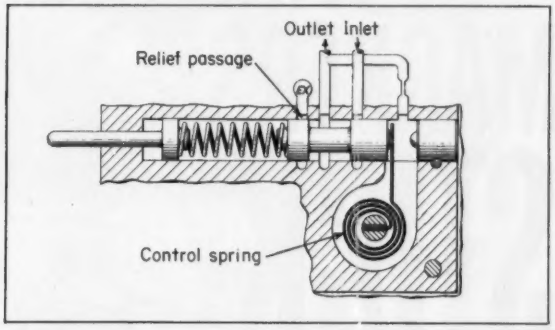
small control forces are needed to operate the valve. *Patent* 2,964,023 *assigned to Pneumo Dynamics Corp., Cleveland, Ohio, by John W. Meulendyk.*

Low-Friction Vibration Damper

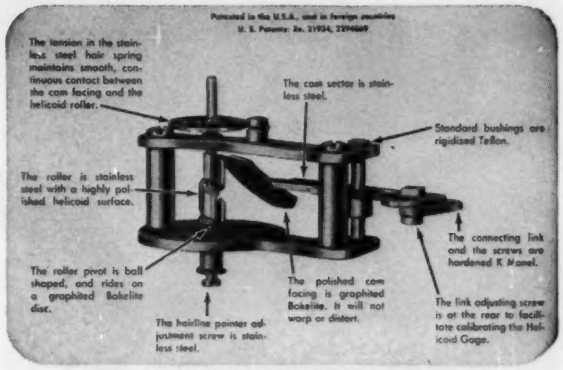


Ball-bearing supports maintain precise spacing between the flywheel and housing of a viscous torsional vibration damper. Since there is no contact, the possibility of binding caused by friction is eliminated. Such binding sometimes occurs when silicone fluids are used as damping and lubricating fluids. This construction permits the use of materials other than ferrous metals for the housing and flywheel. *Patent* 2,966,074 *assigned to Houdaille Industries Inc., Buffalo, N. Y., by Rollin Douglas Rumsey.*

Temperature-Sensitive Regulator Valve



An adjustable thermal control spring in a regulator valve helps to maintain a preset pressure even when low temperatures cause a rise in viscosity which tends to produce abnormally high pressures. Fluid from the outlet line is directed to a control chamber, where it acts on the face of the control valve to regulate outlet pressure. When the fluid is cold, the temperature-sensitive control spring deflects to the left, moving the control-valve spool to decrease system pressure by closing the inlet port and opening the relief port. As the fluid temperature rises, the control spring is deflected to the right. At operating temperature, the spring is inoperative. *Patent* 2,965,120 *assigned to General Motors Corp., Detroit, Mich., by Kenneth E. Snyder.*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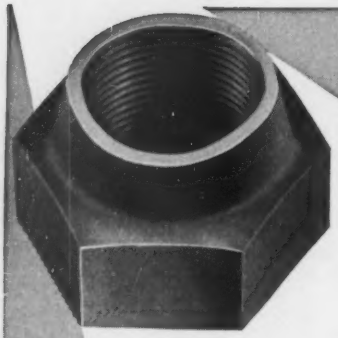

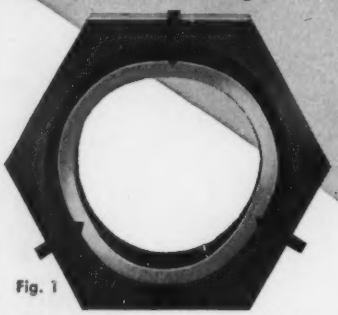

Fig. 1

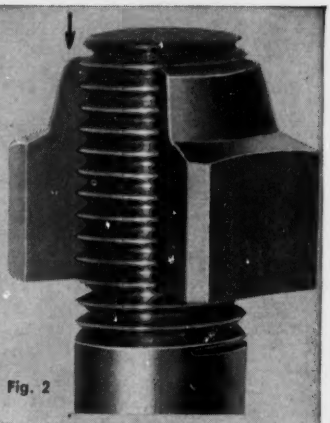

Fig. 2

Three sectors of the tapered portion of the CONELOK nut are preformed inwardly (Fig. 1). When the Nut is applied to a bolt, these conforming sectors are elastically returned to a circular configuration and create an inward and downward pressure which produces intimate contact between the load carrying flanks of the nut and bolt threads (Fig. 2). The shape of the cone sector displacement insures conformity with the mating bolt and maximum friction contact area. . . . The closed stress path in the locking portion of the nut and the advantageous distribution of locking pressure, produce a locking device of high fatigue life . . . and equivalent locking force is exerted at only a fraction of the stress of any slotted type locknut. CONELOK maintains its locking action through many re-applications. . . . It is adaptable to high, and low torque assemblies . . . to high torque stop-nut applications . . . and may be obtained in sizes from No. 10 through 1½", Full and Thick dimensions are "Standard". . .

Send for brochure which includes complete engineering specifications.

NATIONAL MACHINE PRODUCTS COMPANY

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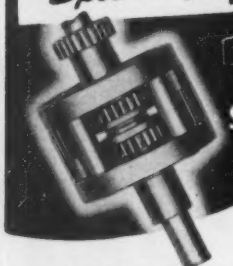
Circle 501 on Page 19

Solve Control Problems of
Speed – Torque – Instruments
WITH
Milwaukee
SMALL DIFFERENTIALS



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Design Engineers! Use these small, precision made, mechanical differentials where measuring or controlling of speeds is involved. They are adaptable to many other applications, such as: Control of Torque, Speed Changing, Remote Controls, Broad Range Step Transmission, Position Controllers or Follow-up System, Clutches, Sequence Controllers.

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BY THE INVENTIVE FOUNDRY PIONEERS AT

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You name the desired parts characteristics, and, if high conductivity copper casting can possibly fill the bill, FALCON is ready to help you explore, develop and produce. Why FALCON? Because there probably is no other foundry in the nation with as impressive a history in new development and experience of personnel. If you have a notion about casting, we want to talk to you.

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LOWELLVILLE, OHIO

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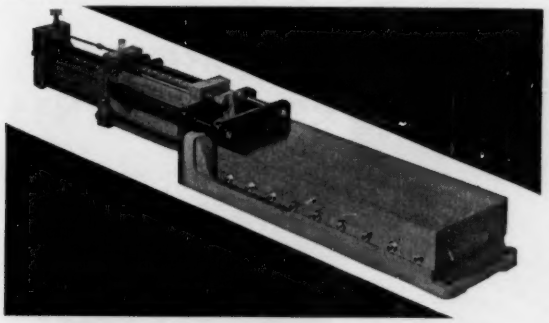

NEW Air-Hydraulic CYLINDER POWERS Heavy-Duty Slide Assemblies

Electro-Mechano's new air-hydraulic cylinder provides the power for the Russell T. Gilman slide assembly shown here.

Any required cycle of fast, slow and skip-feed strokes can be arranged with rapid advance to any point in the stroke and controlled feed. This cycle can be repeated several times during one out-stroke.

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CF&I's new Spring Design and Development department is fully equipped to service your most urgent spring requirements on a priority basis.

You send us a blueprint, sketch or rough sample of the spring that you need (giving complete information as to how the part will function), and CF&I engineers will design and produce several prototypes for you.

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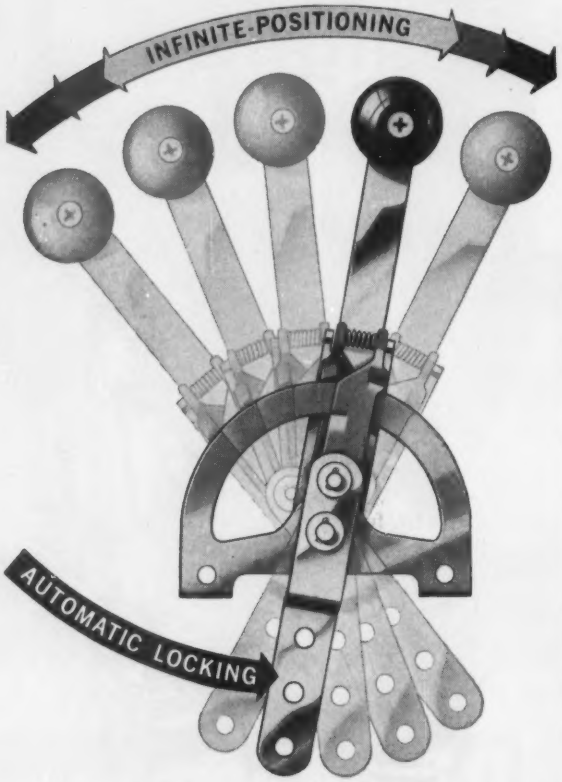
Circle 506 on Page 19

the ADAMS RITE QUADRASTAT CONTROL



APPLICATION:

...wherever positive control and automatic self-locking are required.

The Adams Rite QUADRASTAT Control employs a self-locking principle which permits infinite-positioning through use of the primary handle, but absolutely prevents any creepage or change of setting due to vibration or "feed-back" forces acting through the driven or actuating lever.

Uniquely engineered and comprised of only 5 main elements, the sturdy but lightweight QUADRASTAT is presently in trouble-free use on a wide range of control operations. It has been successfully incorporated into such diverse applications as tractor throttles, hydraulic valves, governors, air ducts, power boats, jet engines, and aircraft drag-brakes. The versatile unit may be manually, hydraulically, or motor controlled, and is available with handle, actuating lever, and quadrant mounted in various positions.

To learn how the QUADRASTAT can solve your control problem, write today for complete details and specifications, Department C-3.

"Over half a century"

ADAMS RITE
MANUFACTURING COMPANY
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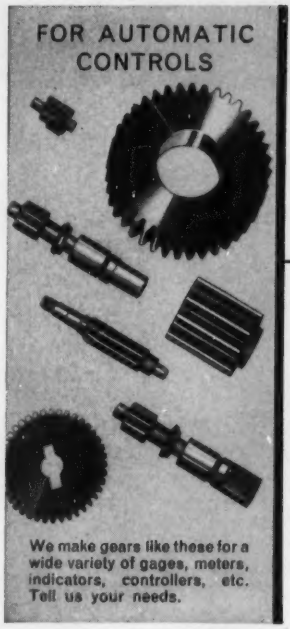
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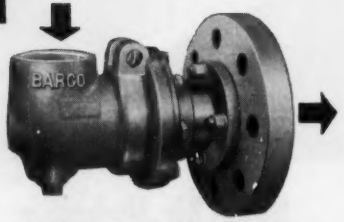
BARCO *Flanged* **ROTARY JOINTS**

Designed for easy installation and accurate control of concentricity.



NEW TYPE CF

HERE is the rotary joint by Barco that gives you everything you want in design and performance:

EASY INSTALLATION—Only an end wrench required to draw up or loosen 4 nuts for installation or removal.

CONTROLLED CONCENTRICITY—No rotating "wobble". Accurate pilot diameter on sleeve establishes and holds concentricity. Tight seal.

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Designer's Fact File from DENISON

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New infinitely-variable, Multi-Range Flow Control solves problem of uniform feed-rate on machine tools. Precision-built in three standard sizes—¼", ⅜", ¾"—for pressures to 3,000 psi. Features: Extra-sensitive flow selection. Simple, foolproof operation. Temperature compensated. Needs no external drain. Built to JIC Standards.

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PUMPS • MOTORS • CONTROLS

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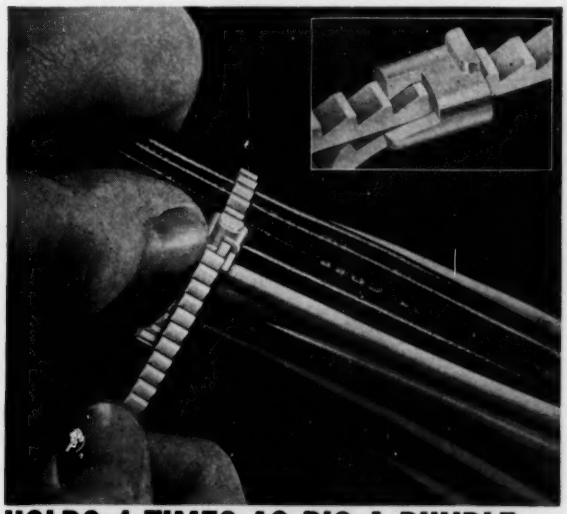

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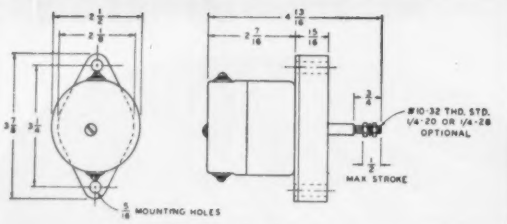
D. C. SOLENOIDS



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(Holding)
1.6A. .8A. .4A. .3A.

DUTY
Continuous

CYCLES
Not to exceed 6 per minute

PULL
Approximately 10 lbs. over ½" stroke

WEIGHT
2¼ pounds

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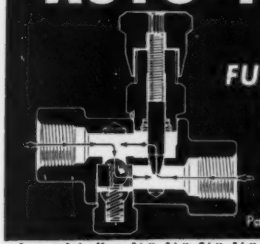

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Flow Control, Needle, Check, for HYDRAULIC Power

Model KF Flow Control Valve with Dial and Knob adjustment for direct reading and duplicating reference. Now available in Aluminum for 3000 psi.

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A complete line: ⅛", ¼", ⅜", ½", and ¾" female Dryseal Pipe Sizes in all models and types. Equivalent Aeronautical Tube Sizes on special order.

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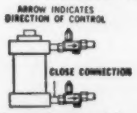
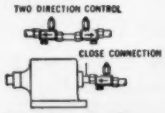
Model PF Knob and Dial Flow Control Valve or Model PN Needle Valve for panel mounting.

Model C Check Valve for In-Line Mounting.

TYPICAL APPLICATIONS



Controlling Double Acting Cylinder



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SWIVEL JOINTS

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Zinc and aluminum die castings by Paramount are big contributing factors to the Marien Custom Color Dispenser's long-lived accuracy and economical cost. **Quality** is the reason why Marien, like a long list of die casting users, chose **Paramount.**

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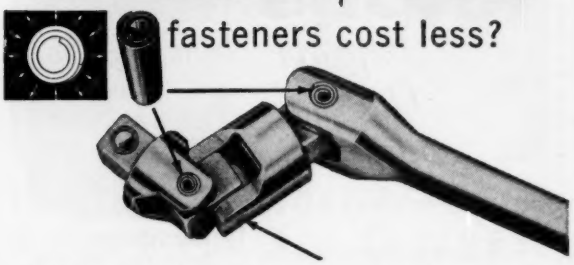
fasteners cost less?



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3. Assembly costs are lowered with SPIROL PINS! Just drill the hole (plus and minus tolerances allowed only by SPIROL PIN) and drive the pins—automatically or by hand.
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16Q

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Your resident 'Buffalo' Engineering Representative is qualified to help you get the right unit for every job.

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'Buffalo' Air Handling Equipment to move, heat, cool, dehumidify and clean air and other gases.

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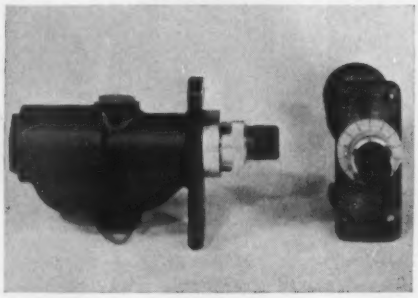
NEW pressure compensated LOW FLOW rate regulator



controls Flow as low as 2 cubic inches per minute.

Accuracy of ±10% over a pressure differential of 1000 psi at 2 CIPM.

Especially good for machine tools, air-oil cylinders, jet engine starters, or wherever a low rate of oil or fuel flow must be controlled accurately.

Designed for panel mounting on test stands or bracket mounted in pipe lines.

Built-in check valve provides free flow in reverse direction.

Adjustable between 2 and 90 cubic inches per minute.

Write for illustrated circular with blueprint.

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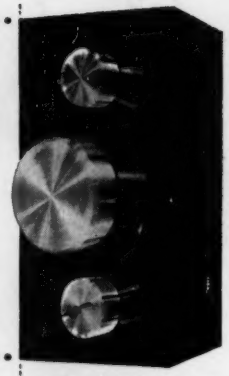
distinctive KNOBS *improve Quality equipment!*



These solid one-piece knobs, accurately hand-crafted from Dural, add a custom touch to fine equipment. Their smart, satin-smooth machined finish and fluted sides harmonize perfectly with ultra-modern product designs.

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1"	11/16"
1-1/4"	11/16"
1-1/2"	11/16"
2"	11/16"
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One type cam . . . no special cam lobes required.

Snap Action Switches, N. O. and N. C.—electrically separated

2 through 12 circuits. Available in NEMA 1, 4, 5, 7, 9 and 12 enclosures.

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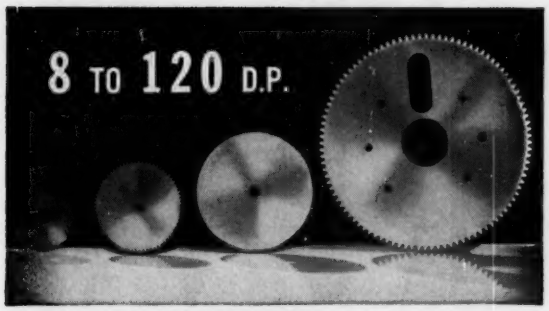

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AIR GASES LIQUIDS

connect or disconnect the fastest and easiest way

Just plug in . . . the patented PUSHOMATIC locking mechanism automatically forms a positive leak-proof connection . . . no turning or twisting necessary. Connect to most sockets and plugs regardless of make . . . because the **Series D is interchangeable** . . . interchangeability saves valuable set-up time and reduces costly inventories.

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360° swivel action reduces operator fatigue and eliminates aggravating hose kinking and twisting.

The **Series D interchangeable** coupling can be used on air, gases, or liquid lines which makes it ideal for most industrial uses. Maximum flow with minimum pressure drop. The performance and construction of the Series D Coupling meets Military Specifications MIL-C-4109-A.

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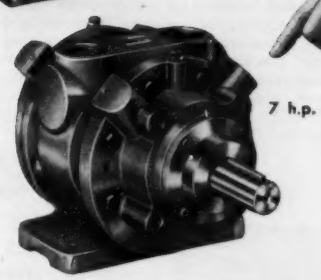
Specify Air Power!

STOCKED FOR IMMEDIATE SHIPMENT



Use variable-speed, explosion-proof

GAST AIR MOTORS

Need a compact, low-cost motor for original equipment or plant use applications? *Air may be your answer . . .* using one of these efficient Gast rotary-vane Air Motors. Look at the special advantages they offer you:

1. They're explosion-proof — no sparks, no danger!
2. Low initial cost compared to other motors.
3. Speed variable with simple valve control.
4. Can't burn out if overloaded or stalled.
5. Reversible rotation optional on some models.
6. Rotor vanes take up their own wear.
7. Quickly attached to plant air lines.
8. Amazingly light, compact for h.p. delivered.
9. Ball-bearing; almost service-free design.
10. Mechanically simple, neat in appearance.

Gast Air Motors are supplied as original equipment on pneumatic hoists, mixers for paint and chemicals, fans, blowers, fuel hose-reel rewinders, liquid pumps, spooling machines and a host of other products. Used in explosive atmospheres and in "hot" locations to 250° F.

Model No.	1AM	2AM	4AM	6AM	8AM	16AM
H.P. at 90 P.S.I., 2000 RPM	0.13	0.57	1.1	2.0	4.0	7.0
Weight, lbs.	1½	5½	8	17	25	65

For complete performance data, write for Air Motor Bulletins. Specify models that interest you.

THEY'LL DRIVE EQUIPMENT 4 WAYS:

AIR MOTORS • VACUUM PUMPS • COMPRESSORS

GAST MANUFACTURING CORP.
P.O. BOX 117-P, BENTON HARBOR, MICHIGAN

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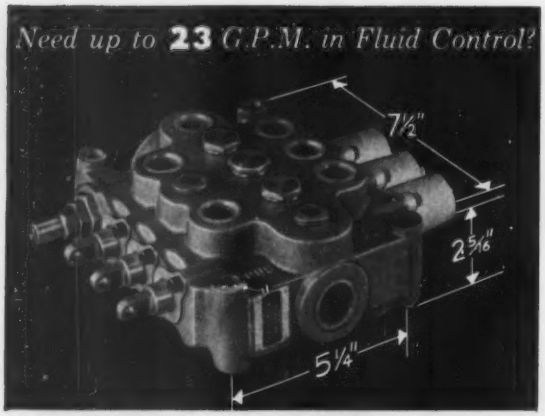
Need up to **23** *G.P.M. in Fluid Control?*



COMPACT HUSCO 3300-SP MULTI-PLUNGER VALVE IS FOR YOU!

One of five basic sizes, HUSCO 3300-SP Valve offers unusual design and performance features that adapt it to wide application. Available to control up to *six* individual cylinders, single or double acting, permitting up to *four* positions of control for extreme versatility. Conventional or parallel circuit, check valve controlled. Compact, precision built for long, trouble-free service. Other HUSCO Multi-Plunger Valves in capacities from 3 to 185 G.P.M.

Write for detailed specifications on HUSCO 3300-SP and complete catalog "Husco's House of Ideas" — or engineering aid on your hydraulic control needs.

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PUMPS • VALVES • CYLINDERS

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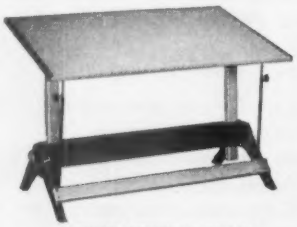
MAYLINE



Economical Drafting Tables Of Wood!

V-MODEL PEDESTAL TABLE

For efficient, sturdy, economical, long lasting wood drafting tables investigate Mayline products. Tables are both attractive and practical. They are sturdily built of Oak, with solid Basswood steel end cleat tops, which can be tilted thru an angle of 50 degrees.

Prices for the V-Model pedestal tables start at $65.55, and $98.25 for the 4-Post tables. Your local dealer can tell you more about these fine drafting tables.

MAYLINE CO., INC.

601 NO. COMMERCE ST.

SHEBOYGAN, WISCONSIN

WOOD 4-POST TABLE

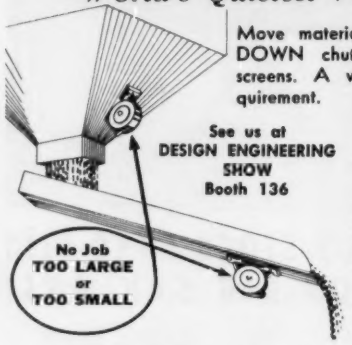
MAYLINE

MAYLINE

MAYLINE

VIBROLATOR® VIBRATION INDUCERS

"World's Quietest Vibrators"



Move materials OUT of hoppers, DOWN chutes and THROUGH screens. A vibrator for every requirement.

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FEATURES:

- LONG LIFE
- RUGGED
- POWERFUL
- UNIQUE DESIGN
- PATENTED THROUGHOUT
- UNCONDITIONAL GUARANTEE

FREE 30-DAY TRIAL ON ALL SIZES.

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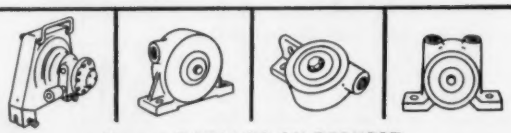

42-page CATALOG ON REQUEST

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Specializing in Applied Vibration

100 Designer St., Neponset, Illinois

VIBROLATOR

● VIBROLATOR is Martin Engineering's registered trade mark for vibration inducers and vibrator accessories.

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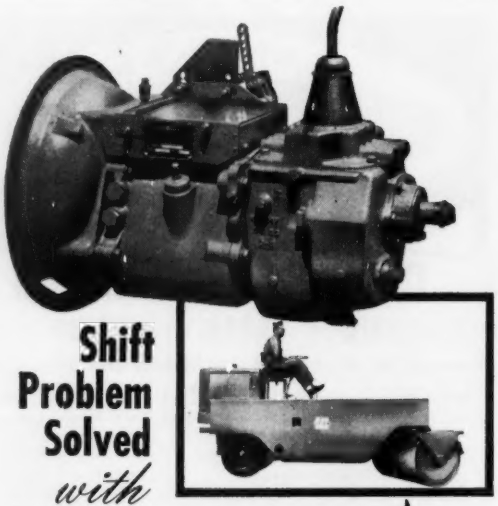

Shift Problem Solved *with*

FUNK revers-O-matic®

On this Browning Road Roller, a FUNK Revers-O-Matic® allows the operator to change both speed and direction — *with just one lever.* Hands are left free for other operations. Shifting is smooth and instant, with no wheel spinning.

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FUNK MFG. CO. Box 577-F Coffeyville, Kan.

Circle 529 on Page 19

Circle 530 on Page 19

POWER SUPPLY PROTECTION!

sub-miniature thermal magnetic

CIRCUIT BREAKER

Series 43-500.00-SI
featuring—

- auxiliary contacts N.O., N.C.
- power failure indication
- elimination of fuses
- push button operation
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RATED: 50 milliamps to 10 amps
240 V A.C., 65 V D.C.

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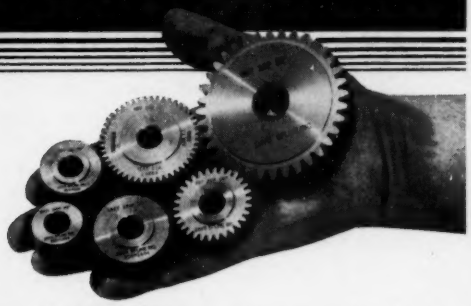
ULTRA-HIGH PRECISION



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- Hardened and Ground Tool Steel

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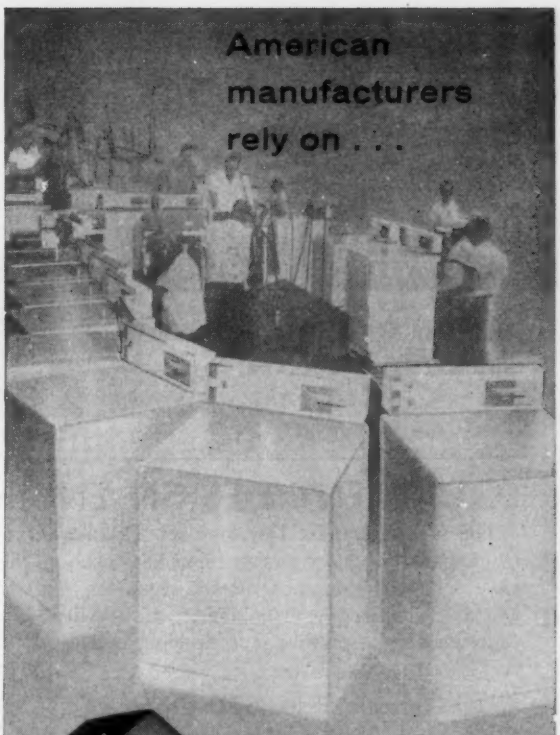

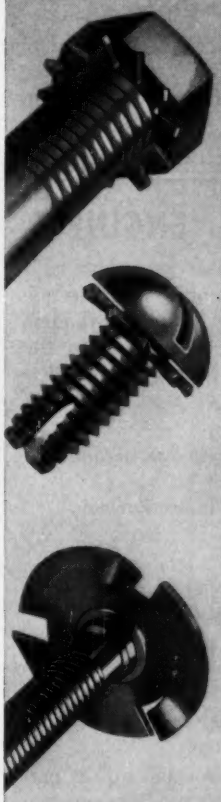

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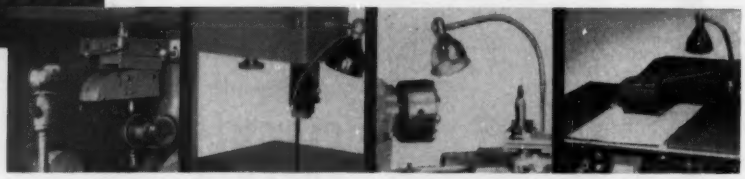
VIMCO Lights
SINCE 1919
SUPPLEMENTARY LIGHTS

PROTECT YOUR EQUIPMENT from variations in plant or office lighting by assuring a constant, comfortable light source in the work area . . . with Vimcolights.

In use for over 40 years, easy-to-install Vimcolights are instantly adjustable, yet hold firm.

Six standard models and many variations to handle oil splash or heavy vibration problems. Special designs. Write for Catalog O-4.

VIMCO MFG. CO., INC.
500 MAIN ST. HOLLAND, N. Y.



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EQUIPMENT DESIGN ENGINEER

The Research and Development Division of a major paper producer has an immediate opening for an experienced equipment design engineer. This is a highly challenging assignment with excellent advancement opportunities in a growing company.

YOU SHOULD HAVE:

1. Degree in Mechanical Engineering.
2. Minimum of 3 years experience in the design of medium heavy machinery (converting machinery or paper machinery field preferred but not essential).
3. Knowledge of strength of materials, mechanisms, and other engineering fundamentals as far as they apply to equipment design.
4. Ability to direct others in the preparation of detail drawings and layouts.

This is an excellent opportunity to use your initiative and creative ability in an atmosphere conducive to accomplishment.

Salary open. Age to 35.

Send complete resume in strictest confidence to: **Box 987 MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.**

WANTED: DESIGN ENGINEER

This firm needs an engineer who has solid talent in the area of mechanical and electro-mechanical machine design and who enjoys exercising his talent both on the board and in the shop. This is primarily a boardwork position concerned with the design of food processing machinery.

Candidates must have knowledge of and skill with:

1. All standards related to mechanical machine design;
2. Machine dynamics;
3. Metals and metal-forming techniques;
4. Costs related to the above;
5. The ability to put all of this together into a high producing engineering effort characterized by inventive creativity.

This is a truly professional-level engineering position. It is NOT administrative.

The Department is new and small and is part of a dynamic national consumer products corporation. Assisting and subordinate draftsmen are available. Position is located in our SOUTHERN CALIFORNIA headquarters.

Send resume, including salary requirements to BOX 986, MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

ENGINEERS
AVAILABLE OR WANTED

WANTED: Mechanical Engineer graduate for Research and Development laboratory of manufacturer of steam heating specialty items. Experience in design of steam traps, regulators, temperature controls and heating specialties preferred. Attractive salary, opportunity for advancement, liberal company benefits, etc. Send resume of education, experience and qualifications to Personnel Director, Sarco Manufacturing Corporation, Bethlehem, Pennsylvania.

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BPA NBP

backtalk——

—A New Veep

Most recently editor-in-chief of *Steel*, our sister publication, Irwin H. Such is now vice president - editorial for the Penton Publishing Co. In this capacity, he will serve as consultant to and editorial representative of all our publications.

This appointment renews, officially, an old editorial acquaintance between Irwin and MACHINE DESIGN. During the early part of his career, he was one of Penton's editorial representatives in the New York office and was, therefore, listed on our masthead. Irwin was named engineering editor of *Steel* in 1943, editor in 1946, and editor-in-chief in 1956.

—Old Reliability

Current-events reading re-emphasizes the importance of reliability, also the subject of the article on Page 76.

In a few weeks' time, unreliable computers made the papers by passing out $40,000 worth of duplicate stock dividends, failing a number of college students who actually had passing grades, reporting wrong scores on 1000 college-entrance exams, and over-estimating a county's 1961 tax receipts by $28 million. Also, a lie detector was exposed as a chronic fibber.

We offer two comments: 1. Tsk, tsk. 2. Read, or reread, "Reliability Audits."

—No Longer Under Wraps

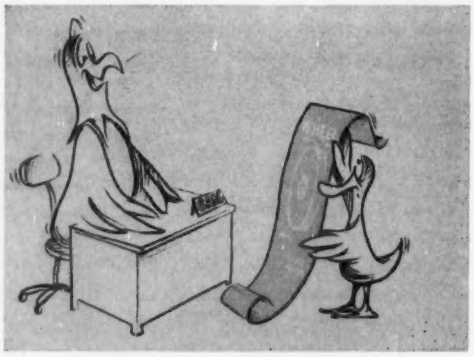
Wearing only a bikini-sized covering, in the form of an address label, this issue initiates MACHINE DESIGN's new mailing system.

Originally mailed in envelopes, our magazines shed part of their bulky wraps in the early 1950's, when we went to a wrapper-type enclosure with the address printed from a metal plate. Now, labels come from huge reels of tape, imprinted by a Scriptomatic machine from punched cards. The cards, besides their data-filled holes, carry typed addresses with inked backs, good for 175 impressions. We'll never wear them out, of course, since our girls in Circulation will make new cards after checking recipients each year.

Advantages of the new system are varied: It speeds the ever-growing mailing job, cuts chances of error, and reduces change-of-address time to about three weeks. Also, in puncturing cards and tape, the machines produce very fine confetti.

—Why a Bird Crosses the Govt.

A new bird book, *Strictly Birdsmanship* (or *How To Lay the Egg That Kills the Golden Goose*), stars an eagle and some lesser species and has to do with Government and Industry and their partnership in the area of scientific research and development. This partnership, says author Bernard S. Benson, "must be made to work superbly if as a nation we are to excel." Mr. Benson offers examples of unsuperbness,



"Tremendous idea—come back when the Russians have done it and we'll be able to get it sponsored with no trouble at all."

based on his experiences as president of Benson-Lehner Corp., an electronic manufacturer "firmly and satisfactorily entrenched in the defense industry."

The book is generously cartooned by Jack Roberts of the Carson-Roberts advertising agency, Los Angeles.

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NEW CORED FORGING METHOD

saves on parts and assemblies

This book describes the Bridgeport Cored Forging Process, and tells how weight, machining or assembly can be reduced on simple or complex parts.

Castings, ordinary forgings and assemblies have been economically replaced by these impact-type cored forgings to produce stronger and better looking finished parts. Savings range from significant to considerable.

✓	closer tolerances
✓	denser, stronger grain
✓	less machining to finish
✓	no assembly required
✓	thinner walls or sections
✓	less finished weight
✓	multiple coring
✓	lower cost plating
✓	less scrap/rejects

Send for Bridgeport's Forgings Book which describes how these major benefits can lower costs for you.

CORED FORGINGS DIVISION
BRIDGEPORT
BRASS COMPANY
1000 Connecticut Ave., South Norwalk, Conn.

Circle 535 on Page 19

Zero burnout time and minimum "haloing" are combined in CDF's new grade 614 glass fabric epoxy laminate at no increase in price over conventional NEMA G-10 grades. Available plain or copper-clad, 614 is a cold punch material that is also superior in flame retardancy, has excellent trichloroethylene vapor resistance and low moisture absorption. The grade is distinguished by its opacity and its tan color.

Result: Another example of CDF leadership in meeting critical military and industrial applications while effecting important customer savings!

Typical properties of 614 (1/16" thickness):

Burnout Time, sec.	0
Water Absorption	0.10
Flexural strength, psi, lw	75,000

(Copper-clad 614 meets MIL-P-13949B, Type GF Plain meets NEMA G-10; approval pending for MIL-P-18177B, Type GEE. Also pending under NEMA proposed FR-4)

CDF® CONTINENTAL-DIAMOND FIBRE

CONTINENTAL-DIAMOND FIBRE CORPORATION, NEWARK, DELAWARE • A SUBSIDIARY OF THE Bird COMPANY

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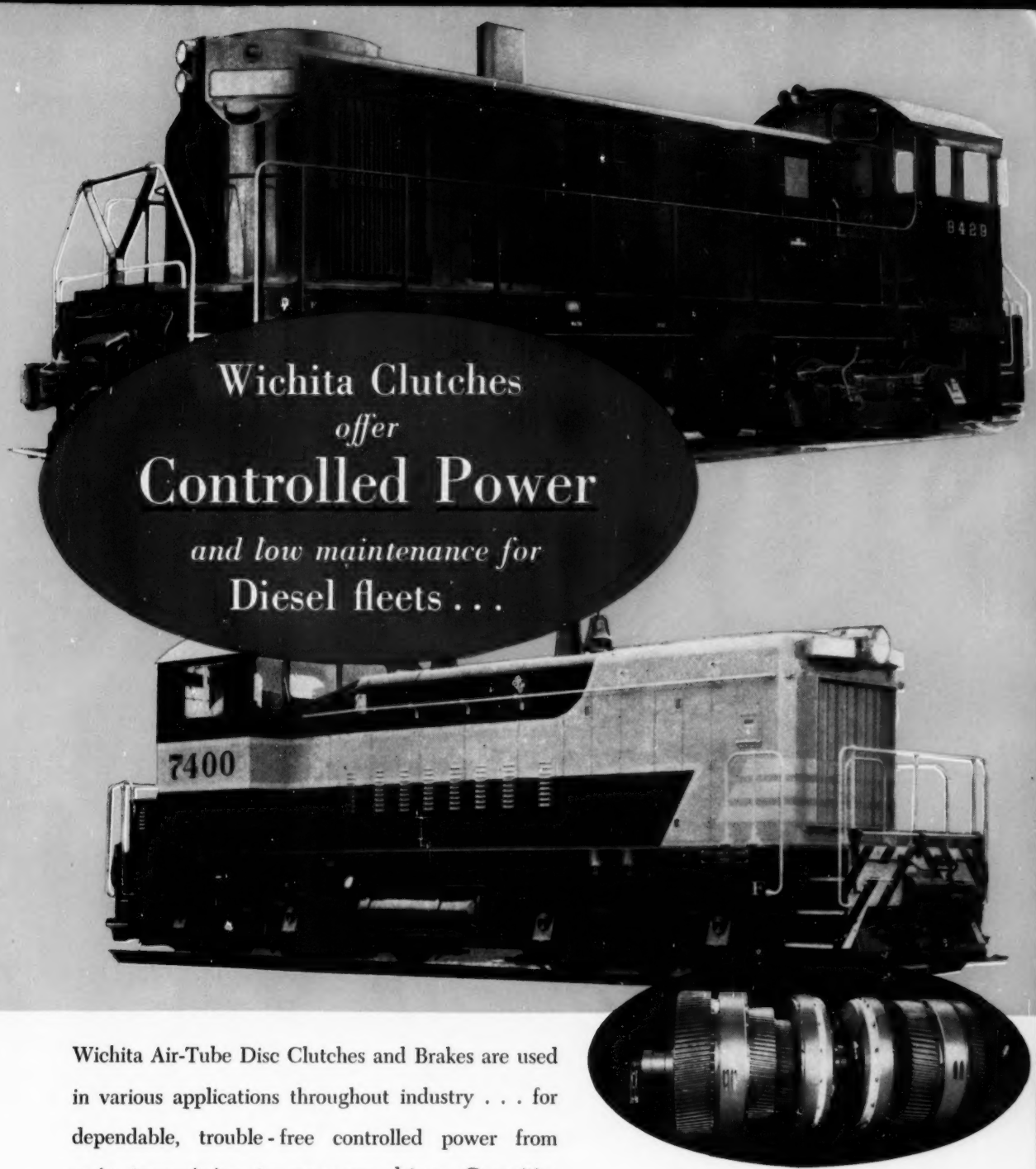

Wichita Clutches *offer* Controlled Power *and low maintenance for* Diesel fleets . . .

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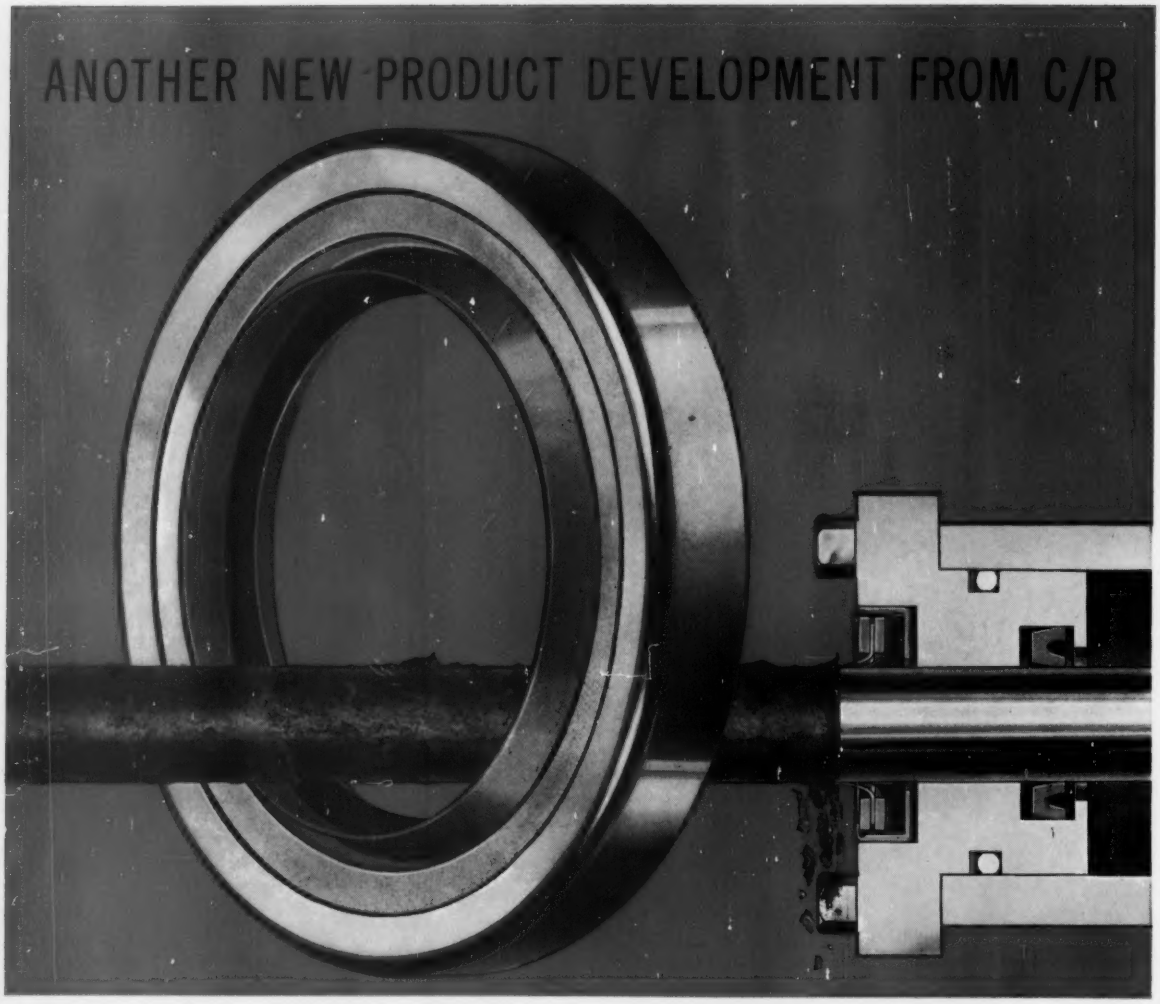

New Wiper-Scraper Seal for Cylinders

Scrapes off ice, mud, tar – wipes off water, dust, other contaminants

Now, you can effectively exclude dirt and other contaminants from hydraulic cylinders under the most severe field conditions. One compact unit, the C/R SC Wiper-Scraper Seal does the job. Formerly, a separate rod scraper had to be installed in front of the ordinary wiper seal. The special machining necessary, plus the scraper ring, and retaining ring made this an expensive installation.

Chicago Rawhide's SC Wiper-Scraper Seal combines a spring brass scraper and synthetic rubber wiping member in one steel shell. The I.D. of the scraper is slightly under shaft size to provide a snug fit that will remove tar or frozen mud, but it has sufficient play within the shell to tolerate any off-center conditions of the rod such as caused by bearing "bore-slop." The cost is much lower than any other combination of scraper and wiper. "Design-in" cost is low, assembly simple. Most important is the performance contribution to the cylinder. The additional value of longer packing life and increased operating dependability with the SC Wiper-Scraper Seal will far outweigh the nominal cost.

For complete information, specifications and standard sizes, write for your copy of C/R's new Bulletin SC-100

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